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PURPOSE OF THE INSTITUTE.

It is the purpose of the Institute, by means of conventions and publications, to increase and disseminate knowledge in regard to the use of cement, concrete and allied products; to conduct research into their properties and uses; and to formulate recommended practice and standard specifications.

Its objects are purely educational.

* In place of B. F. Affleck, resigned.
† In place of W. L. Church resigned.

JOURNAL
OF
AMERICAN CONCRETE INSTITUTE

FOUNDED 1905, AND INCORPORATED 1906, AS
NATIONAL ASSOCIATION OF CEMENT USERS
CHARTER AMENDED JULY 2, 1913

The Institute is not responsible, as a body, for statements and opinions advanced in its publications

VOL. III JANUARY, 1915 NO. 1

ELEVENTH ANNUAL CONVENTION

The Eleventh Annual Convention of the Institute will be held at the Auditorium Hotel, Chicago, Ill., February 9–12, 1915. This Convention will mark the completion of the tenth year of the existence of the Institute, and an especially interesting and profitable program is being arranged. The sessions will be at 10 A. M., 3 P. M. and 8 P. M.

TENTATIVE PROGRAM—ELEVENTH ANNUAL CONVENTION

Tuesday, February 9, 1915. 10.00 o'clock, A. M.

Concrete Roads and Bridges.

Opening Address of Welcome.

Review of Present Practice in Concrete Road Construction.

Percy H. Wilson, Secretary, Association of American Portland Cement Manufacturers, Philadelphia, Pa.

The Service Test Concrete Road in Philadelphia.

William H. Connell, Chief, Bureau of Highways and Street Cleaning, Philadelphia, Pa.

Reinforcing Narrow Concrete Roads.

John W. Mueller, Civil Engineer, New Castle, Ind.

Report of Committee on Concrete Roads.

A. N. Johnson, Chairman.

3.00 o'clock P. M.

Concrete Roads and Bridges.

Organization and Methods of Constructing Concrete Roads.

William Acheson, Division Engineer, New York State Highway Commission, Buffalo, N. Y.

Concrete Roads and Frost Action.

A. M. Lovis, First Assistant Engineer, Massachusetts Highway Commission, Boston, Mass.

Cost of Construction and Maintenance of Concrete Roads.

H. J. Kuelling, County Highway Commissioner, Milwaukee, Wis.

The Construction of Integral Curbs.

Charles E. Russell, City Engineer, Highland Park, Ill.

Comparative Cost of Concrete Roads.

Percy H. Wilson, Secretary, Association of American Portland Cement Manufacturers, Philadelphia, Pa.

8.00 o'clock P. M.

Test of a Reinforced Concrete Slab Bridge.

E. B. McCormick, Mechanical Engineer, Office of Public Roads, Washington, D. C.

Standard Designs for Concrete Highway Bridges and Culverts.

C. B. McCullough, Designing Engineer, Iowa State Highway Commission, Ames, Ia.

Report of Committee on Standard Specifications for Concrete Highway Bridges and Culverts.

Willis Whited, Chairman.

Wednesday, February 10, 1915. 10.00 o'clcok, A. M.

Concrete and Reinforced Concrete Tests and Design.

Report of Committee on Concrete and Reinforced Concrete.
A. E. Lindau, Chairman.

Report of Committee on Nomenclature.
F. C. Wight, Chairman.

Report of Committee on Insurance.
J. P. H. Perry, Chairman.

The Design of Wall Columns and Wall Beams.
Edward Smulski, Consulting Engineer, Boston, Mass.

12.00 o'clock Noon.

Close of Ballot Box.

3.00 o'clock P. M.

Reinforced Concrete Stands, Stadias and Bowls.
Charles W. Leavitt, Civil and Landscape Engineer, New York, N. Y.

Design and Construction of the Massachusetts Institute of Technology Buildings.
Sanford E. Thompson, Consulting Engineer, Newton Highlands, Mass.

The Design of Concrete Bins for the Storage of Cement.
Leonard Wesson, Assistant to President, Universal Portland Cement Company, Chicago, Ill.

The Manufacture and Laying of Concrete Sewer Pipe.
Henry T. Shelley, Assistant Engineer in Charge of Sewer Construction, Philadelphia, Pa.

Tests on Egg-Shape and Circular Reinforced Concrete Sewer Pipe.
Albert T. Goldbeck, Engineer of Tests, Bureau of Surveys, Philadelphia, Pa.

8.00 o'clock P. M.

Concrete and Reinforced Concrete Tests and Design.

Annual Address by the President.

A Critical Review of Current Practice in Reinforced Concrete as Embodied in Building Regulations and the Joint Committee Report.

Edward Godfrey, Structural Engineer, Robert W. Hunt and Company, Pittsburgh, Pa.

Basis of Current Practice in Design of Reinforced Concrete Structures.

C. A. P. Turner, Consulting Engineer, Minneapolis, Minn.

A New-Old Theory for Reinforced Concrete in Bending.

L. J. Mensch, Contracting Engineer, Chicago, Ill.

Thursday, February 11, 1915. 9.00 o'clock A. M.

Business Session.

Annual Report of Board of Direction. Report of Tellers.

10.00 o'clock A. M.

Concrete in Art and Architecture.

Report of Committee on Cement Products.

C. K. Arp, Chairman.

Cement Roofing Tile.

J. S. Freund, General Manager, American Cement Tile Manufacturing Company, Pittsburgh, Pa.

Some Principles of Design as Applied to Concrete Houses.

Charles E. White, Jr., Architect, Chicago,

The Fireproof Home.

R. P. Stoddard, Executive Secretary, Society Advocating Fire Elimination, Cleveland, Ohio.

3.00 o'clock P. M.

Report of Committee on Treatment of Concrete Surfaces.
L. C. Wason, Chairman.

A New and Simple Method for Securing Dustless Concrete Floors.
P. M. Bruner, P. M. Bruner Granotoid Company, St. Louis, Mo.

Topical Discussion on the Dusting of Concrete Floors.

8.00 o'clock P. M.

Report of Committee on Edison Fire.
Cass Gilbert, Chairman.

Concrete: A Medium of Æsthetic Expression.
Irving K. Pond, Architect, Chicago, Ill.

Synthetic Stone in Catskill Aqueduct Buildings.
H. Lincoln Rogers, Architect, Board of Water Supply, New York, N. Y.

Friday, February 12, 1915. 10.00 o'clock A. M.

Plant Management and Cost.

Contractor's Equipment, Austin-Nichols Warehouse.
T. A. Smith, General Superintendent, Turner Construction Company, New York, N. Y.

Mechanical Plant for Handling Concrete.
William P. Anderson, President, Ferro Concrete Construction Company, Cincinnati, Ohio.

The Strength of Concrete Forms.
Harrison S. Taft, Contracting Engineer, Seattle, Wash.

Concrete Forms for the Catskill Aqueduct.
Alfred D. Flinn, Deputy Chief Engineer, New York Board of Water Supply, New York, N. Y.

3.00 o'clock P. M.

Report of Committee on Methods of Tests and Standard Specifications for Concrete Materials.
Sanford E. Thompson, Chairman.

Mixing, Curing and Placing Concrete with High Pressure Steam.
Harold P. Brown, New York, N. Y.

Some Further Results Obtained in Investigating the Properties of Portland Cement having a High Percentage of Magnesia.
P. H. Bates, Chemist, Bureau of Standards, Pittsburgh, Pa.

8.00 o'clock, P. M.

Annual Banquet in celebration of Tenth Anniversary.

Proposed Amendment to By-Laws.

The following proposed amendment to the By-Laws will be considered at the Business Session, at 9 o'clock A. M., on Thursday, February 11, 1915.

Change Article IX, Section 2, now reading—

"SECTION 2.—The annual dues of each member shall be five dollars."

to read—

"SEC. 2.—The annual dues of each member shall be ten dollars."

RULES GOVERNING THE AWARD OF THE LEONARD C. WASON MEDAL.

This prize is to be awarded annually, unless the Board of Direction shall decide that none of the papers presented during the year are of such character as to merit the award.

Committee on Award

1. The Board of Direction shall appoint annually, not later than six months after the annual convention of each year, three members, not members of the Board of Direction, who shall form a committee to recommend the award of the prize.

2. The papers considered shall include all papers published by the Institute during the year or the period between two conventions.

3. The Committee on Award shall report its recommendation to the Board of Direction at least one month before the next convention, and the award shall be made by the Board of Direction.

4. Announcement of the award shall be made at the annual convention.

5. The Secretary of the Institute shall act as Secretary of the Committee on Award, but shall have no vote or voice in its deliberations.

Code of Rules.

I. Competition for the medal of the American Concrete Institute shall be restricted to members of the Institute.

II. There shall be one bronze medal awarded as hereinafter provided. The dies therefor shall be deposited with the superintendent of the United States Mint at Philadelphia in trust, exclusively for the above purpose.

III. All original papers presented to the Institute by members and published by the Institute during the year for which the medal is awarded shall be open to the award, provided that such papers shall not have been previously contributed in whole or in part to any other association nor have appeared in print prior to their presentation to a convention, except that the printing of advance copies in the journal prior to a convention shall not bar the papers from competition for the award.

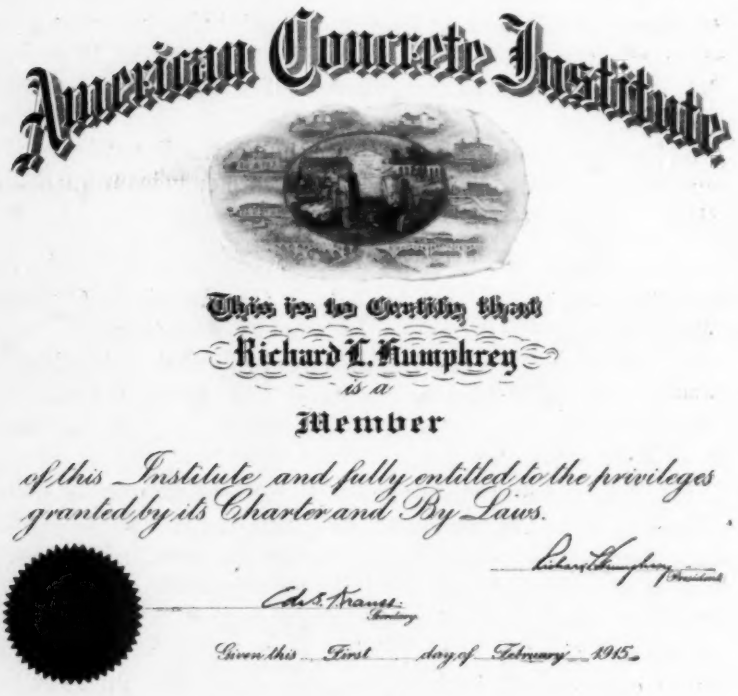
IV. The medal shall be awarded for a paper which shall be judged most worthy of special commendation for its merits.

MEMBERSHIP CERTIFICATE.

A Certificate of Membership in this Institute will be furnished to any member in good standing, i. e., whose dues are paid up to date. These Certificates are printed from an engraved steel plate. The name of the member is engrossed and the Certificate will be signed by the President and Secretary. The Certificates are about 10 x 14 ins., and have sufficient margin to be framed 14 x 17 ins. They are engraved on parchment or parchment paper, both suitable for rolling or framing.

The charge for certificates is as follows:

Parchment	$2.50
Parchment Paper	1.50


American Concrete Institute
This is to Certify that
Richard L. Humphrey
is a
Member
of this Institute and fully entitled to the privileges granted by its Charter and By Laws.
Given this First day of February 1915.

MEMBERSHIP CERTIFICATE.

Synopses of Recent Articles on Concrete.

Reviewed December 1 to 31, 1914.

The synopses given below are for the purpose of keeping the members of the Institute in touch with the leading articles of interest appearing in the many technical journals and is not a complete review of the journal. The publications regularly reviewed appear below and the number given corresponds to the number following the title of the paper. The length of the article in pages, whether illustrated or not, is noted, and the publications reviewed in which it appears:

1. Canadian Engineer, Toronto, Ontario, Canada.
2. Cement, New York, N. Y.
3. Cement Era, Chicago, Ill.
4. Cement World, Chicago, Ill.
5. Concrete Age, Atlanta, Ga.
6. Concrete Era, Los Angeles, Cal.
7. Concrete-Cement Age, Detroit, Mich.
8. Concrete and Constructional Engineering, London, England.
9. Engineering and Contracting, Chicago, Ill.
10. Engineering News, New York, N. Y.
11. Engineering Record, New York, N. Y.
12. Good Roads Magazine, New York, N. Y.
13. Portland Cement, Kansas City, Mo.
14. Rock Products, Chicago, Ill.
15. Proceedings American Railway Engineering Association, Chicago, Ill.
16. Western Contractor, Record Building, Kansas City, Mo.
17. Journal National Fire Protection Association, Boston, Mass.
18. Journal Western Society of Engineers, Chicago, Ill.
19. Proceedings American Society of Civil Engineers, New York, N. Y.
20. Proceedings American Society of Municipal Improvements, New York.
21. Proceedings American Society for Testing Materials, Philadelphia, Pa.
22. Proceedings Engineers' Club of Philadelphia, Philadelphia, Pa.
23. Proceedings Engineers' Society of Western Pennsylvania, Pittsburgh, Pa.
24. Professional Memoirs, Corps of Engrs., U. S. A., Washington, D. C.
25. Proceedings Institution of Civil Engineers, London, England.
26. Transactions, Canadian Society of Civil Engineers, Montreal, Quebec, Canada.
27. Railway Age Gazette, Chicago, Ill.
28. Better Roads, Jamestown, Ohio.

MATERIALS

Use and Tests of Unscreened Gravel; Illinois State Highway Department. (10) Dec. 17, 2 pp., ill. Use of unscreened or pit-run gravel for concrete, as prescribed by the department.

Painting Reinforcing Material. (7) Dec., 3½ pp. Discussion by various engineers on materials and effects.

The Use of Turned Sections in Tension Tests of Reinforcing Bars, by E. P. Withrow and L. C. Niedner. (21) 1914, 16 pp., ill. Result of tests conducted at the Municipal Testing Laboratory of St. Louis.

Errors in the Methods of Determining the Time of Setting of Cement, by G. M. Williams. (21) 1914, 23 pp., ill.

Volume Changes in Portland Cement and Concrete, by A. H. White. (21) 1914, 42 pp., ill.

Additional Results Obtained with the Autoclave Test for Portland Cement, by H. J. Force. (21) 1914, 9 pp., ill.

Proportioning Aggregates for Portland-Cement Concrete, by Albert Moyer. (21) 1914, 25 pp.

Blast Furnace Slag as Aggregate in Concrete, by W. A. Aiken. (21) 1914, 18 pp.

Testing Concrete Aggregates, by Cloyd M. Chapman. (21) 1914, 12 pp., ill.

Relation Between Deformation and Deflection in Reinforced-Concrete Beams, by G. A. Maney. (21) 1914, 11 pp., ill.

Examination of Concrete Failures for Their Determining Causes, by R. S. Greenman. (21) 1914, 18 pp., ill.

Paint Protection for Portland-Cement Surfaces, by H. A. Gardner. (21) 1914, 2 pp., ill.

A Simple Compression Machine for Testing Structural Materials, by William O. Lichtner. (21) 1914, 5 pp. A high-capacity machine hydraulically operated by one man; compact and economical in operation.

BUILDINGS

A New Flat-Slab Reinforced-Concrete Floor with Striking Features. (10) Dec. 17, 1¼ pp., ill. Description of staggered-column supported floors over basements of armature room and oil-storage building, Cleveland Railway Co. shops, store building.

The Lesson of the Edison Fire. (10) Dec. 17, ½ p. Some precautions in fireproof buildings emphasized by this conflagration.

The Fire in the Edison Works at West Orange, N. J. (10) Dec. 17, 4½ pp., ill. A detailed account of the fire.

Portable Buildings of Monolithic Reinforced Concrete. (10) Dec. 24, ½ p., ill. Description of small hexagonal or octagonal buildings 4 to 8 ft. in diam. for oil houses, cabins, booths, waiting stations, shelters, etc.

Some Further Lessons from the Edison Conflagration. (10) Dec. 24, ¾ p. Continuation of article (10) Dec. 17.

Some Facts Emphasized by the Edison Fire. (9) Dec. 30, ⅓ p.

Sulphite-Solution Plant of Reinforced Concrete. (11) Dec. 5, ½ p. Four 99-ft. towers 8.5 ft. in diam. with special tile lining containing the limestone, at Erie, Pa.

Cost of Floors for Buildings. (11) Dec. 12, ¾ p. Unit costs of various types of floor with structural concrete or similar material base.

Disastrous Fire at Edison Factory. (11) Dec. 19, 2 pp., ill. A detailed account of fire. This number also includes ½ p. editorial comment on same.

How to Erect Small Concrete Buildings. (14) Dec. 7, 1½ pp., ill. Poultry houses, hog pens, garages, etc.

The Wallace-Scott Tailoring Institute, Glasgow. (8) Dec., 11 pp., ill. Design and construction of reinforced concrete building main block frontage 160 ft. with two side wings extending back 200 ft.; total height 62 ft., floors 15 ft. in clear, wings 50 ft. wide.

Concrete on the Farm. (4) Dec., 2 pp., ill. Suggestions for floors, mangers, and gutters in up-to-date dairy barn.

Concrete Chimneys. (4) Dec., 2 pp., ill. Small concrete chimneys in houses.

BRIDGES AND RAILROAD WORK

Tearing Out a Reinforced-Concrete Subway. (10) Dec. 3, 1 p., ill. 800 cu. yds. structure removed in New York City.

Plant and Working Methods on Approaches to North Side Point Bridge. (10) Dec. 3, 2½ pp., ill. 900 ft. on both sides of Allegheny River Bridge at Ohio River junction; 17,300 cu. yds. concrete and 28,000 lin. ft. concrete piles.

Some Bridges on the Columbia Highway. (10) Dec. 10, 5 pp., ill. Design and construction of concrete bridges and viaducts from Biggs to Astoria, through Portland, Ore.

The New York Rapid Transit Railway Extensions, by F. Lavis. (10) Dec. 10, 5 pp., ill. Description of Lexington Ave. lower-level and four-track tunnels.

New York Rapid Transit Railway Extensions, by F. Lavis. (10) Dec. 31, 4½ pp., ill. Last of serial article, describing typical concrete plants, design and construction of the elevated concrete structure at Queens Boulevard.

Reinforced-Concrete Bridge with Cantilever Abutments. (11) Dec. 5, 1 p., ill. Design of bridge at overhead crossing, Hallstead, Pa.; on the D. L. & W. 50 ft. bridge carrying four tracks, 13 ft. on centers, placed on a 300-ft. spiral of a 2-deg. curve. Has many novel features.

Floors for Steel Highway Bridges in Illinois. (11) Dec. 19, 1½ pp., ill. Includes data on plain and reinforced concrete sub-floors; weight and influence on bridge design.

Concrete Handrails on Kansas City Terminal Work. (11) Dec. 19, ⅔ p., ill. Unit construction cast at central plant, used on 1¾ mi. of viaduct.

Chief Features in Building a Long Concrete Viaduct at St. Louis. (11) Dec. 26, 1⅗ pp., ill. Reinforced-concrete structure 2224 ft. long, including 2000 concrete piles 25–35 ft. long driven with two types of hammers; some construction features of special interest.

Reinforced-Concrete Highway Arch for Grade Separation. (11) Dec. 26, 1 p., ill. Design of viaduct carrying road across D. L. & W. R. R. at New Milford, Pa. A 75.6 ft. arch loaded at crown only.

Construction of the Gwynn's Falls Arch Bridge. (27) Dec. 4, 3¼ pp., ill. 4-track concrete structure on Pa. R. R. at Balto., Md., in two sections. Length 580 ft., width 61 ft.; three 115 ft. and one 75 ft. arch spans.

Tidewater Activities at Halifax. (1) Dec. 10, 1 p., ill. Description of widest pier in Canada, floor area 258,000 sq. ft.; concrete freight shed with temporary accommodation for 2,000 passengers; difficulties of construction occasioned much admiration.

Rosedale Section, Bloor Street Viaduct. (1) Dec. 17, 2½ pp., ill. Portion No. 2 of Proposed $2,500,000 structure to bridge valleys in northeast Toronto. 1618-ft. section; plan and elevation and estimated quantities. About 16,900 cu. yds. of concrete in piers, approaches, retaining wall, floor slabs, etc.

Concrete Bridge in Main, at Falmouth. (4) Dec., ½ p., ill. Design of bridge 147 ft. over all, 24 ft. roadway, 5 ft. sidewalks; 2 spans, 64 ft.; cost, $11,000.

Water Pressure in Concrete Pile Sinking. (4) Dec., 2¾ pp., ill. Pre-cast piles sunk (not hammered) to 50 ft. penetration except through solid rock. Claimed to be better than steel piling with greater penetration.

Methods and Costs in Constructing the 450-ft. East Fourth Street Viaduct at Fort Worth, Texas. (7) Dec., 7 pp., ill. 450 ft. long over all, 42 ft. 6 in. wide, nine spans of 50 ft. c. to c. of piers.

A Discussion of the Essentials of Design of Reinforced Arch Structures. (7) Dec., 3 pp., ill.

Retaining Wall to Support Butler St., near Baker St., Pittsburgh. (7) Dec., 1¼ pp., ill. Description of wall 13 ft. high, 18 in. at top 10 ft. 9 in. at base to prevent street from slipping into river, due to quicksand.

RESERVOIRS, DAMS, CANALS, ETC.

Draining Land by Wells; Concrete Drain Head. (10) Dec. 10, ½ p., ill. Work successfully done; wells 20 to 45 ft. deep draining ½ to ¾ acre.

Grouting Foundations for Gravity-Section Dam. (11) Dec. 12, 1 p., ill. Holes 40 ft. deep and 10 ft. apart drilled and grouted in soft shale underlying sandstone quartzite at Calgary Power Co. Plant, Alta.

Toronto Breakwater to Curb 10-foot Waves. (11) Dec. 26, 2 pp., ill. Heavy concrete blocks molded separately to be set in walls by cranes and capped with mass concrete; steel protection plates against ice. A $19,000,000 project.

Storage Dam at Eugenia Falls. (1) Dec. 10, 3 pp., ill. Description of Hydro-Electric plant of the Power Commission of Ontario. 1900 ft. of structure, corewall with earth embankment; total concrete required about 10,000 cu. yds.

Hydraulic Plant, Joliette, Que. (1) Dec. 17, 1¼ pp., ill. Solid concrete overflow dam about 230 ft. long, varying from 5 to 7½ ft. in depth; width from 2 ft. at top to 11 ft. at base. Solid concrete headgate entrance to flume and reinforced concrete power house.

Concrete for Coast Protection. (4) Dec., 3½ pp., ill. Designs and construction of work in Southern California and New England; light sea-wall to check ocean encroachment.

Concreting an Oil Pipe Line. (4) Dec., 1¾ pp., ill. Eight miles of steel pipe buried in Louisiana marsh lands protected.

Sanitary Swimming-Pools. (4) Dec., 3 pp., ill. Ingenious design to eliminate dangers of water pollution.

ROADS AND PAVEMENTS

Concrete-Road Building with Small Concrete Mixers. (10) Dec. 10, ¾ p., ill. Use of two mixers and 16 men at Centralia, Wash.

A Projected Concrete Toll Road for Automobiles in Texas. (10) Dec. 17, ¾ p. A discussion on cost, maintenance, etc., of such roads as private enterprise.

Concrete Pavement Design. (9) Dec. 16, 1 p. Article on development and use of methods of designing concrete pavements.

Concrete Street and Alley Paving and Curb Construction in Gary, Ind. (9) Dec. 23, ½ p., ill. Construction of curbs integral with pavement and paid for as such.

Road Building with Industrial Equipment. (11) Dec. 5, ¾ p., ill. Use of 12-car train and 20 H. P. Dinkey, giving unit costs and time performance of work, etc., on about 12 miles road, Eastern Shore of Maryland.

Highway Program of Cook County, Illinois. (11) Dec. 12, ½ p., ill. Organization and equipment used for construction, maintenance and proposed work.

Concrete Roads, by H. J. Kueling, Highway Commissioner, Milwaukee Co., Wis. (11) Dec. 19, ⅔ p. Width and thickness, cement and aggregate, placing and curing and joints.

Curb Costs Curbed. (4) Dec., ½ p., ill. Curbs and gutters built integral with concrete roads and pavements.

A Concrete Highway in California. (3) Dec., 7 pp., ill. Road building during 1913 and 1914; some comparative figures with California in the lead and characteristics of construction.

SEWERS, PIPE, TILE, ETC.

Construction of the Metcalf Ave. Sewer, Borough of the Bronx, New York City. (10) Dec. 10, 3¼ pp., ill. Single and double sewer of large capacity constructed of reinforced concrete throughout; section pile founded.

Beargrass Creek Storm-Water Channel at Louisville, Ky. (10) Dec. 24, 4½ pp., ill. Design and construction of practically an open main sewer reconstructed with concrete to form a storm-water channel; 40 to 70 ft. wide, 4 to 24 ft. retaining walls including gravity, cantilever and counterfort sections.

MISCELLANEOUS

Handling Construction Material by Aerial Tramways. (10) Dec. 10, 1½ pp., ill. New State Penitentiary Buildings at Bellefonte, Pa. Handling materials from quarry to site for concreting plant. Work will extend over several years.

Thermophones in Kensico Dam. (10) Dec. 10, ¾ p. ill. Study of stresses resulting from expansion and contraction of masonry on the new Catskill Aqueduct.

The Palmer Memorial Stadium at Princeton University. (10) Dec. 10, 4 pp., ill. Design and construction of largest reinforced-concrete stadium, seating 41,000 people.

Concrete Anchor Piles for Steel Sheeting. (10) Dec. 17, ¾ p., ill. New coal pier at Sandusky, Ohio, supported by octagonal anchor piles 18 in. diam. used in a line of steel sheeting.

Portable Hoist Towers for Concreting. (10) Dec. 31, 2¾ pp., ill. Traveling tower between mixer and work and mixer and tower mounted on separate flat-cars at Poughkeepsie, N. Y.

Large Floating Gravel-Washing Plant in Indiana. (11) Dec. 19, ½ p., ill. Max. cap. 300 cu. yd. per hr. Said to be largest of its kind. Equipment and operation.

Canal Zone Construction. (14) Dec. 7, 1 p., ill. Account of wet process of concrete hollow tile plant operated by Panama Canal Commission.

Preventable Losses on Concrete Jobs. (14) Dec. 7, ⅔ p. Hints on equipment, tools, sacks, left-over material, etc.

Use of Hydrated Lime in Concrete. (14) Dec. 7, ⅔ p. Quality of lime in combination, density of mixture, mixing, etc.

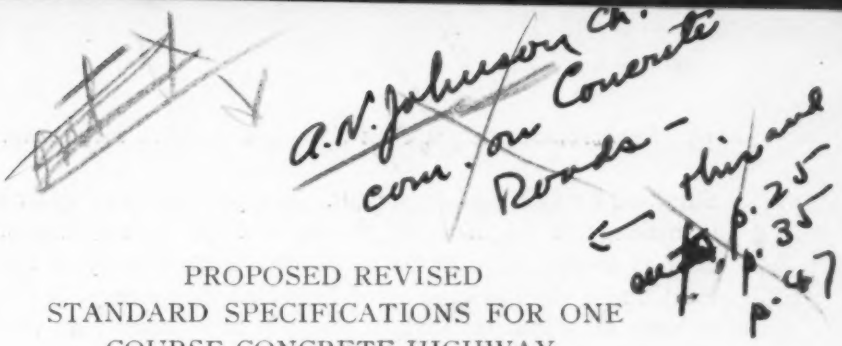
Growing Products Plant at Joliet. (3) Dec., 3 pp., ill. Description of plant manufacturing concrete products.

Collapsible Steel Centering. (8) Dec., 4 pp., ill. Some notes on economic use of steel in view of heavy increased cost of timber.

Foundation for Pumping Plant. (4) Dec., ¾ p., ill. Description of plant with capacity of one million gallons per minute, in Louisiana; 248 ft x 45 ft. x 7 ft. deep; piles to 60 ft. under surface.

Some Records of Operation in Handling Concrete with Compressed Air. (7) Dec., 4 pp., ill. Tunnel lining work.

Teaching the Boys to Use Concrete, by L. A. Warner. (3) Dec., 2 pp., ill. Manual training concrete and work done at various institutions in United States.



PROPOSED REVISED STANDARD SPECIFICATIONS FOR ONE COURSE CONCRETE HIGHWAY.

I. Materials.

1. *Cement.*—The cement shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society (Standard No. 1).

2. *Aggregates.*—Before delivery on the job, the contractor shall submit to the engineer a fifty (50) pound sample of each of the fine and coarse aggregates proposed for use. The samples shall be tested and if found to pass the requirements of the specifications similar material shall be considered as acceptable for the work. All aggregates used shall meet with the approval of the engineer and shall fulfill the requirements of these specifications. In no case shall aggregates containing frost or lumps of frozen materials be used.

Fine Aggregate.—Fine aggregate shall consist of sand or screenings from hard, tough, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain vegetable matter nor more than three (3) per cent of clay or loam.

Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement, and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of briquettes composed of one (1) part of the same cement and three (3) parts

Standard Ottawa sand by weight. The percentage of water used in making the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of Standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement of the American Society of Civil Engineers.

Coarse Aggregate.—Coarse aggregate shall consist of clean, hard, tough, durable crushed rock or gravel graded in size, free from vegetable matter, and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half (1½) inch round opening and shall range from one and one-half (1½) inch down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch, and no intermediate sizes shall be removed.

3. *Mixed Aggregate.*—Crusher run stone, bank run gravel or artificially prepared mixtures of fine and coarse aggregate shall not be used.

4. *Water.*—Water shall be clean, free from oil, acid, alkali or vegetable matter.

5. *Reinforcement.*—All reinforcement shall be free from rust scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than seventy thousand (70,000) pounds per square inch and bend one hundred eighty (180) degrees around one diameter and straighten without fracture.

6. *Joint Filler.*—Joint filler shall consist of prepared strips of fibre matrix and bitumen, or similar material of approved quality, one-quarter (¼) inch in thickness. Where the joints are protected with metal plates the joint filler shall be made to conform to the cross-section of the pavement and where unprotected joints are used, the width shall be at least one-half (½) inch greater than the thickness of the pavement at any point.

7. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than two and one-half (2½) inches in depth and not less than one-eighth (⅛) nor more than one-quarter (¼) inch average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of

installation of joint protection plates shall be approved by the engineer.

8. *Shoulders.*—Materials for the construction of shoulders shall be approved by the engineer.

II. GRADING.

9. *Defined.*—Grading shall include all cuts, fills, ditches, borrow pits, approaches and all earth or rock moving for whatever purpose where such work is an essential part of or necessary to the prosecution of the contract.

10. *Engineer's Stakes.*—Stakes will be set by the engineer for the center line, side of slopes, finished grade and other necessary points properly marked for the cut or fill. When the grade line is approached the final grade stakes will be set for which ..... days' notice must be given to the engineer.

11. *Excess Material.*—Excess material shall be disposed of as directed by the engineer, the free haul not to exceed .... feet.

12. *Over-Haul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of ..... cents per cubic yard for each additional ..... feet.

13. *Cuts and Fills.*—In cuts the final grade shall be obtained by rolling with a roller weighing not less than five (5) nor more than ten (10) tons. The engineer shall determine the depth of material to be thus compacted. When a fill of one (1) foot or less is required to bring the surface to grade, all vegetable matter shall be removed before making the fill.

Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers the first of which shall extend entirely across from the toe of the slope on one side to the toe of the slope on the other side and successive layers shall extend entirely across embankments from slope to slope. Each layer, which shall not exceed one (1) foot in depth, shall be thoroughly rolled with a self-propelled roller weighing not less than five (5) nor more than ten (10) tons. The roller shall pass over the entire area of each layer of the fill at least twice. The sides of the embankment shall be kept lower than the center during all stages of the work and the surface main-

tained in condition for adequate drainage. The use of muck, quicksand, soft clay or spongy material which will not consolidate under the roller is prohibited.

When the material excavated from the cuts is not sufficient to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed, the cross-section of the roadbed shall conform to the cross-sectional drawings and profile attached hereto.

14. *Slopes.*—All slopes must be properly dressed to lines given by the engineer.

III. DRAINAGE.

15. *Drainage.*—The contractor shall construct such drainage ditches as will insure perfect sub- and surface-drainage during construction and such work shall be completed to the satisfaction of the engineer, prior to the preparation of the roadbed, as herein specified.

Tile drains shall be placed as shown in the drawings attached hereto. Tile to be laid in the trench at least ..... (.....) inches wide and .....(.....) feet deep below the established grade of the finished road. Such trench shall be back filled with crushed stone or pit run gravel, with fine material removed, which, after light tamping shall be .....(.....) inches in depth.

Open ditches must be constructed along the concrete road as shown on the attached drawing, the dimensions, side slopes and grade of said ditches being as shown on the cross-section drawings and profile attached hereto.

At the time of the acceptance of the road, the ditches must be in perfect condition with clean slopes and bottom, containing no obstruction to the flow of water.

IV. SUB-GRADE.

16. *Construction.*—The bottom of the excavation or the top of the fill when completed shall be known as the sub-grade and shall be at all places true to the elevation as shown on the plans attached hereto.

The sub-grade shall be brought to a firm, unyielding surface

by rolling the entire area with a self-propelled roller weighing not less than five (5) nor more than ten (10) tons, and all portions of the surface of the sub-grade which are accessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed one hundred (100) square inches in area. All soft, spongy or yielding spots and all vegetable or other perishable matter shall be entirely removed and the space refilled with suitable material.

When considered necessary or of assistance in producing a compact, solid surface, the sub-grade before being rolled shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel or macadam, the latter shall be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material and rolled to make a dense, tight surface of the roadbed.

17. *Acceptance.*—No concrete shall be deposited until the sub-grade is checked and accepted by the engineer.

V. FORMS.

18. *Materials.*—Metal or wooden forms shall be free from warp, of sufficient strength to resist springing out of shape, and shall be equal in width to the thickness of the pavement at the edges. Wooden forms shall be of not less than two (2) inch stock, and shall be capped with two (2) inch angle iron.

19. *Setting.*—The forms shall be well staked or otherwise held to the established line and grades, and the upper edges shall conform to the established grade of the road.

20. *Treatment.*—All mortar and dirt shall be removed from the forms that have previously been used.

VI. PAVEMENT SECTION.

21. *Width, Thickness of Concrete and Crown.*—The concrete pavement shall be ..... feet wide ....(.....) inches in depth at center, and ....(.....) inches in depth at the sides. The finished surface shall conform to the arc of a circle, as shown on the plans attached hereto.

NOTE.—Crown shall not be more than one one hundredth (1/100) of the width. The thickness of the concrete at the edges shall not be less than six (6) inches.

VII. JOINTS.

22. *Width and Location.*—Transverse joints shall be one-quarter (¼) inch in width and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet apart. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

23. *Joint Filler.*—All joints shall be formed by inserting during construction and leaving in place the required thickness of joint filler which shall extend through the entire thickness of the pavement.

24. *Protected Joints.**—The concrete at all transverse joints shall be protected with joint protection plates which shall be rigidly anchored to the concrete. The upper edges of the plates shall be even with each other and the adjoining surface of the concrete. All steel plates varying more than one-quarter (¼) inch from the finished surface of the concrete, as shown on the plans attached hereto, shall be ground to meet the specified requirements, or slabs in which such plates occur shall be removed and replaced with new material by the contractor at his expense.

25. *Unprotected Joints.**—All transverse joints shall extend through the entire thickness of the pavement and the filler shall project not less than one-half (½) inch above the finished surface. The concrete adjacent to these joints shall be finished with a wood float, which is divided through the center and which will permit finishing on both sides of the filler at the same time. Before the road is opened to traffic, joint filler shall be cut off to a height of one-quarter (¼) inch above the surface of the road.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

26. *Measuring Materials.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A bag of Portland cement (94 lb. net) shall be considered one (1) cubic foot.

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*When specification "Protected Joints" is to be used, "Unprotected Joints" should be omitted, and *vice versa*.

27. *Mixing.*—The materials shall be mixed in a batch mixer of approved type and mixing shall continue after all materials are in the drum for at least forty-five (45) seconds at a minimum speed of twelve (12) revolutions per minute. The drum shall be completely emptied before receiving materials for successive batches.

28. *Re-tempering.*—Re-tempering of mortar or concrete which has partially hardened, that is, remixing with or without additional materials or water, shall not be permitted.

29. *Proportions.*—The concrete shall be mixed in the proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate and not more than three (3) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the coarse aggregate.

A cubic yard of concrete in place shall contain not less than one and seven tenths (1.7) barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto with the amounts actually used in each section of concrete between successive transverse joints, as determined by actual count of the number of bags of cement used in each section. If the amount of cement used in any three (3) adjacent sections (between transverse joints) is less by more than two (2) per cent, or if the amount of cement used in any one section is less by more than five (5) per cent of the amount hereinbefore required, the contractor shall remove all such sections and replace the same with new materials, according to these specifications, at his expense.

30. *Consistency.*—The materials shall be mixed with sufficient water to produce a concrete which will hold its shape when struck off with a template. The consistency shall not be such as to cause a separation of the mortar from the coarse aggregate in handling.

IX. REINFORCING.

31. *Reinforcing.*—Concrete pavements twenty (20) feet or more in width shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the

pavement shall amount to at least 0.038 square inch per foot, and the cross-sectional area of reinforcing metal, which is perpendicular to the center line of the pavement, shall amount to at least 0.049 square inch per foot.

Reinforcing metal shall not be placed less than two (2) inches from the finished surface of the pavement and otherwise shall be placed as shown on the drawings attached thereto. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches when the lap is made perpendicular to the center line of the pavement, and not less than one (1) foot when the lap is made parallel to the center line of the pavement.

X. PLACING CONCRETE.

32. *Placing Concrete.*—Immediately prior to placing the concrete, the subgrade shall be brought to an even surface. The surface of the subgrade shall be thoroughly wet, but shall show no pools of water when the concrete is placed.

After mixing, the concrete shall be deposited rapidly upon the subgrade, to the required depth and for the entire width of the pavement in successive batches and in a continuous operation without the use of intermediate forms or bulk heads between expansion joints.

In case of a breakdown, concrete shall be mixed by hand to complete the section or an intermediate transverse joint placed as hereinbefore specified at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

33. *Finishing.*—The surface of the concrete shall be struck off by means of a template or strikeboard, which shall be moved with a combined longitudinal and cross-wise motion. When the strikeboard is within three (3) feet of a transverse joint it shall be lifted to the joint and the pavement struck by moving the strikeboard away from the joint; any excess concrete shall be removed. Any holes, left by removing any material or device used in constructing the joint shall be immediately filled with mortar composed of one (1) part of cement and two (2) parts of fine aggregate. Concrete adjoining metal protection plates at

transverse joints shall be dense in character and shall be given a smooth finish with a steel trowel for a distance of six (6) inches each side of the joints.

After being brought to the established grade with the template or strikeboard, the concrete shall be finished from a suitable bridge, no part of which shall come in contact with the concrete. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter (¼) inch from the true shape.

The edges of the pavement shall be rounded as shown on the cross-sectional drawings attached hereto.

XI. PROTECTION.

34. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth or other approved covering is placed. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth or other material approved by the engineer, which cover shall be kept wet for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concrete shall be protected by canvas until such covering can be placed.

Under the most favorable conditions for hardening in hot weather the pavement shall be closed to traffic for at least fourteen (14) days, and in cool weather for an additional time, to be determined by the engineer.

In the season of the year when the average temperature is below fifty (50) degrees Fahrenheit, sprinkling and covering of the pavement may be omitted at the direction of the engineer.

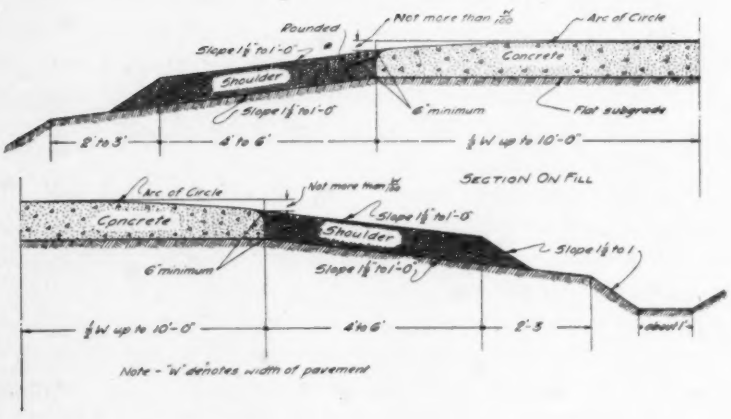
The contractor shall erect and maintain suitable barriers to protect the concrete from traffic, and any part of the pavement damaged from traffic or other causes, occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and disposed of as directed by the engineer.

35. *Temperature Below 35 Degrees Fahrenheit.*—Concrete shall not be mixed or deposited when the temperature is below freezing.

If, at any time during the progress of the work the temperature is, or in the opinion of the engineer, will, within twenty-four (24) hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated, and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen subgrade.

XII. SHOULDERS.

36. *Construction.*—When shoulders are required, they shall be built upon the properly prepared subgrade, as shown on the profile and cross-sectional drawings attached hereto. The work shall be done to the entire satisfaction of the engineer.



PROPOSED REVISED STANDARD SPECIFICATIONS FOR ONE COURSE CONCRETE STREET PAVEMENTS.

I. Materials.

1. *Cement.*—The cement shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society (Standard No. 1).

2. *Aggregates.*—Before delivery on the job, the contractor shall submit to the engineer a fifty (50) pound sample of each of the fine and coarse aggregates proposed for use. These samples shall be tested and if found to pass the requirements of the specifications similar material shall be considered as acceptable for the work. All aggregates used shall meet with the approval of the engineer and shall fulfil the requirements of these specifications. In no case shall aggregates containing frost or lumps of frozen materials be used.

Fine Aggregate.—Fine aggregate shall consist of sand or screenings from hard, tough, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain vegetable matter nor more than three (3) per cent of clay or loam.

Fine aggregate shall be of such quality that mortar composed of one (1) part of Portland cement, and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of briquettes composed of one (1) part of the same cement and three (3) parts Standard Ottawa sand by weight. The percentage of water used in making the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand-

briquettes of Standard consistency. In other respects all briquettes shall be made in accordance with the report of Committee on Uniform Tests of Cement of the American Society of Civil Engineers (see Standard No. 1).

Coarse Aggregate.—Coarse aggregate shall consist of clean, hard, tough, durable crushed rock or gravel graded in size, free from vegetable matter, and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half (1½) inch round opening and shall range from one and one-half (1½) inch down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch, and no intermediate sizes shall be removed.

3. *Mixed Aggregate.*—Crusher-run stone, bank-run gravel or artificially prepared mixtures of fine and coarse aggregate shall not be used.

4. *Water.*—Water shall be clean, free from oil, acid, alkali, or vegetable matter.

5. *Reinforcement.*—All reinforcement shall be free from rust-scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than seventy thousand (70,000) pounds per square inch and bend one hundred eighty (180) degrees around one diameter and straighten without fracture.

6. *Joint Filler.*—The filler for all transverse joints shall consist of prepared strips of fibre matrix and bitumen or similar material of approved quality one-quarter (¼) inch in thickness. Where the joints are protected with metal plates the joint filler shall be made to conform to the cross-section of the pavement and where unprotected transverse joints are used the width shall be at least one-half (½) inch greater than the thickness of the pavement at any point. The filler for longitudinal joints along the curb, where a separate curb is used, shall, at the discretion of the engineer, consist of the same material as specified for the transverse joints or of bitumen which will not become soft enough to flow in hot weather or brittle in cold weather. The thickness of longitudinal joints filled with bitumen shall not be less than one-quarter (¼) inch or more than three-quarters (¾) inch.

7. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than

two and one-half (2½) inches in depth and not less than one-eighth (⅛)) nor more than one-quarter (¼) inch average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of installation of joint protection plates shall be approved by the engineer.

II. GRADING.

8. *Defined.*—Grading shall include all cuts, fills, approaches and all earth or rock moving for whatever purpose where such work is an essential part of or necessary to the prosecution of the contract.

9. *Engineer's Stakes.*—Stakes will be set by the engineer for the center line, finished grades and other necessary points.

10. *Excess Material.*—Excess material shall be disposed of as directed by the engineer, the free haul not to exceed.....feet.

11. *Over-Haul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of.....cents per cubic yard for each additional.....feet.

12. *Cuts and Fills.*—In cuts the final grade shall be obtained by rolling with a roller weighing not less than five (5) nor more than ten (10) tons. The engineer shall determine the depth of material to be thus compacted. When a fill of one (1) foot or less is required to bring the surface to grade, all vegetable and other perishable matter shall be removed before making the fill.

Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, each of which shall extend entirely across the width to be filled. Each layer, which shall not exceed one (1) foot in depth, shall be thoroughly rolled with a roller weighing not less than five (5) nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of each layer of the fill at least twice. The use of muck, quicksand, soft clay, spongy or perishable material, which will not consolidate under the roller, is prohibited.

When the material excavated from cuts is not sufficient to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed, the cross-section of the roadbed shall conform to the cross-sectional drawings and profile attached hereto.

All approaches connecting the specified pavement with other

streets or alleys intersecting shall also be cut or filled, and secured from settlement, to form a slope of not more than one (1) vertical to ten (10) horizontal, as shown on the profile and plans attached hereto.

III. DRAINAGE.

13. *Drainage.*—The contractor shall construct tile or other drains as shown in the drawings attached hereto. Tile to be laid in the trench at least.....(.....) inches wide, and .....(.....) feet deep below the top of the adjacent curb. Such trench shall be back filled with crushed stone or pit run gravel, with sand removed, which after light tamping shall be .....(.....) inches in depth.

14. *Catch Basins.*—All catch basins and manhole tops and all covers of openings of any kind shall be readjusted to the grade by the contractor at his expense.

IV. SUB-GRADE.

15. *Construction.*—The bottom of the excavation or the top of the fill when completed shall be known as the sub-grade and shall be at all places true to the elevation as shown on the plans attached hereto.

The sub-grade shall be brought to a firm, unyielding surface by rolling the entire area with a self-propelled roller weighing not less than five (5) nor more than ten (10) tons, and all portions of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed one hundred (100) square inches in area. All soft, spongy or yielding spots and all vegetable or other perishable matter shall be entirely removed and the space refilled with suitable material.

When considered necessary or of assistance in producing a compact, solid surface, the sub-grade before being rolled shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel or macadam, the latter shall be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material and rolled to make a dense, tight surface of the roadbed.

16. *Acceptance.*—No concrete shall be deposited until the sub-grade is checked and accepted by the engineer.

V. FORMS.

17. *Materials.*—Where forms are required, they shall be free from warp, of sufficient strength to resist springing out of shape. Wooden forms shall be of not less than two- (2) inch stock.

18. *Setting.*—The forms shall be well staked or otherwise held to the established line and grades. Where the curb is to be constructed integrally with the pavement, the upper edge of the side forms shall conform to the top of the curb.

19. *Treatment.*—All mortar and dirt shall be removed from the forms that have previously been used.

VI. PAVEMENT SECTION.

20. *Width, Thickness of Concrete and Crown.*—The concrete pavement shall be .....(.....) feet wide from face to face of curb, ...(.....) inches in depth at the sides. The finished surface shall conform to the arc of a circle as shown on the plans attached hereto.

NOTE.—The thickness of the concrete at the gutter line shall not be less than six (6) inches. When pavements twenty (20) feet or less in width are to be built on approximately level ground and a flat sub-grade is to be used, sufficient fall for drainage at the sides of the pavement along the curb shall be provided by giving the roadbed the same grade as that proposed for the gutter. The crown of all pavements shall not be more than one one-hundredth (1/100) of the width except when deemed advisable by the engineer, the crown of a pavement built on a crowned sub-grade may be increased to one-fiftieth (1/50) of the width to provide sufficient fall for drainage along the sides of the pavement.

VII. JOINTS.

21. *Width and Location.*—Transverse joints shall be one-quarter (¼) inch in width and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet apart. A longitudinal joint not less than one-quarter (¼) inch wide shall be constructed between the curb and the pavement where a separate curb is used. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

22. *Joint Filler.*—All transverse joints shall be formed by inserting during construction and leaving in place the required thickness of prepared strips of fibre matrix and bitumen or similar material of approved quality which shall extend through the entire thickness of the pavement and the entire thickness and height of the integral curb when the latter is specified.

Longitudinal joints along the curb, where a separate curb is specified, shall, at the discretion of the engineer, be formed in the same manner as transverse joints or constructed by filling with bitumen as before specified.

23. *Protected Joints.**—The concrete at all transverse joints shall be protected with joint protection plates which shall be rigidly anchored to the concrete. The upper edges of the plates shall be even with each other and the adjoining surface of the concrete. All steel plates varying more than one-quarter (¼) inch from the finished surface of the concrete, as shown on the plans attached hereto, shall be ground to meet the specified requirements, or slabs in which such plates occur shall be removed and replaced with new material by the contractor at his expense.

24. *Unprotected Joints.**—All transverse joints shall extend the entire thickness of the pavement and the filler shall project not less than one-half (½) inch above the finished surface. The concrete adjacent to these joints shall be finished with a wood float, which is divided through the center and which will permit finishing on both sides of the filler at the same time. Before the pavement is opened to traffic joint filler shall be cut off to a height of one-quarter (¼) inch above the surface of the pavement.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

25. *Measuring Materials.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A bag of Portland cement (94 lb. net) shall be considered one (1) cubic foot.

26. *Mixing.*—The materials shall be mixed in a batch mixer of approved type and mixing shall continue after all materials are in the drum for at least forty-five (45) seconds at a minimum speed of

*When the specification "Protected Joints" is to be used, "Unprotected Joints" should be omitted, and *vice versa*.

twelve (12) revolutions per minute. The drum shall be completely emptied before receiving materials for successive batches.

27. *Re-tempering.*—Re-tempering of mortar or concrete which has partially hardened, that is, remixing with or without additional materials or water, shall not be permitted.

28. *Proportions.*—The concrete shall be mixed in the proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate and not more than three (3) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the coarse aggregate.

A cubic yard of concrete in place, including that in integral curbs when same are used, shall contain not less than one and seven-tenths (1.7) barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto with the amounts actually used in each section of concrete (including integral curbs when used) between successive transverse joints, as determined by actual count of the number of bags of cement used in each section. If the amount of cement used in any three (3) adjacent sections (between transverse joints) is less by more than two (2) per cent, or if the amount of cement used in any one section is less by more than five (5) per cent. of the amount hereinbefore required, the contractor shall remove all such sections and replace the same with new materials, according to these specifications, at his expense.

29. *Consistency.*—The materials for the pavement shall be mixed with sufficient water to produce a concrete which will hold its shape when struck off with a template. The consistency shall not be such as to cause a separation of the mortar from the coarse aggregate in handling.

IX. REINFORCING.

30. *Reinforcing.*—Concrete pavements twenty (20) feet or more in width shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement shall amount to at least 0.038 square inch per foot and the cross-sectional area of reinforcing metal, which is perpendicular to the center of the pavement, shall amount to at least 0.049 square inch per foot.

Reinforcing metal shall not be placed less than two (2) inches from the finished surface of the pavement and otherwise shall be placed as shown on the drawings attached hereto. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches when the lap is made perpendicular to the center line of the pavement and not less than one (1) foot when the lap is made parallel to the center line of the pavement.

X. PLACING CONCRETE.

31. *Placing Concrete.*—Immediately prior to placing the concrete, the sub-grade shall be brought to an even surface. The surface of the sub-grade shall be thoroughly wet but shall show no pools of water when the concrete is placed.

After mixing, the concrete shall be deposited rapidly upon the sub-grade, to the required depth and for the entire width of the pavement in successive batches and in a continuous operation without the use of intermediate forms or bulk heads between expansion joints.

In case of a breakdown concrete shall be mixed by hand to complete the section or an intermediate transverse joint placed as hereinbefore specified at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

32. *Finishing.*—The surface of the concrete shall be struck off for the entire width of the pavement and from back to back of integral curbs when used, by means of a template or strikeboard. Any holes left by removing any material or device used in constructing the joint shall be immediately filled with mortar composed of one (1) part cement and two (2) parts of fine aggregate. Concrete adjoining metal protection plates at transverse joints shall be dense in character and shall be given a smooth finish with a steel trowel for a distance of six (6) inches on each side of the joints.

After being brought to the established grade with the template or strikeboard, the concrete shall be finished from a suitable bridge, no part of which shall come in contact with the concrete. If approved by the engineer, the contractor may use a mechanical striking and finishing machine. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a sur-

face free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter (¼) inch from the true shape.

XI. INTEGRAL CURB.

33. *Construction.*—An integral curb shall be constructed, as shown on the attached drawings, to the established grade and in a continuous line on each side of the street .....(.....) feet from the parallel with the center line thereof, except at all intersections of streets, alleys, and driveways where it shall be returned to the street line and at these intersections it shall be rounded to such a radius as the engineer may direct.

The concrete for integral curbs shall be of the same materials and proportions as that required for the pavement.

After striking off the pavement, the concrete for that portion of the integral curbs above the gutter line shall be immediately deposited.

The top and inside surface of integral curbs shall be given a smooth finish and completed with the pavement to the point of stopping each day's work.

NOTE.—Article 33 to be omitted if separate curb is specified.

XII. PROTECTION.

34. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth or other approved covering is placed. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth or other material approved by the engineer, which cover shall be kept wet for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concerte shall be protected by canvas until such covering can be placed.

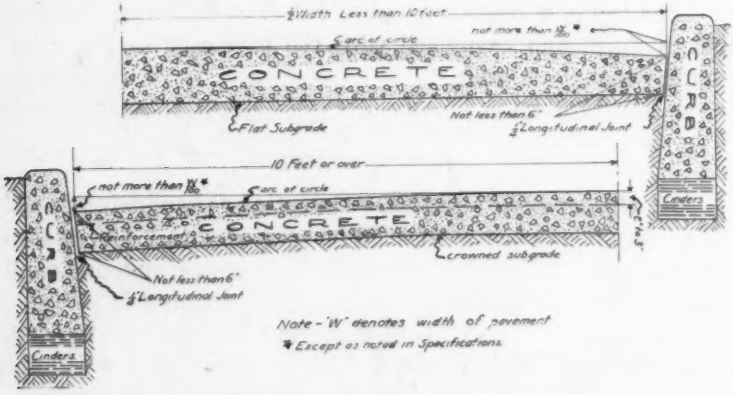
Under the most favorable conditions for hardening in hot weather, the pavement shall be closed to traffic for at least fourteen (14) days, and in cool wether for an additional time, to be determined by the engineer.

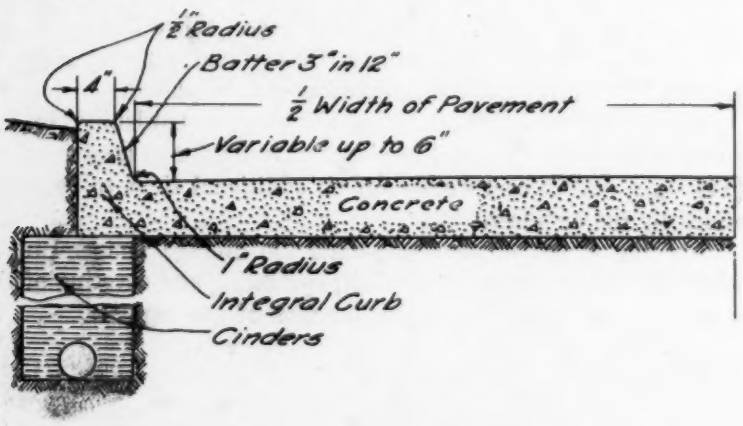
At the season of the year when the average temperature is below fifty (50) degrees Fahrenheit, sprinkling and covering of the pavement may be omitted at the direction of the engineer.

The contractor shall erect and maintain suitable barriers to protect the concrete from traffic and any part of the pavement damaged from traffic or other causes, occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and dispavement may be omitted at the direction of the engineer.

35. *Temperature Below 53 Degrees Fahrenheit.*—Concrete shall not be mixed or deposited when the temperature is below freezing.

If, at any time during the progress of the work the temperature is, or in the opinion of the engineer will, within twenty-four (24) hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen sub-grade.





PROPOSED REVISED STANDARD SPECIFICATIONS FOR TWO COURSE CONCRETE STREET PAVEMENTS.

I. Materials.

1. *Cement.*—The cement shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society (Standard No. 1).

2. *Aggregates.*—Before delivery on the job, the contractor shall submit to the engineer a fifty (50) pound sample of each kind of aggregate proposed for use. These samples shall be tested and if found to pass the requirements of the specifications similar material shall be considered as acceptable for the work. All aggregates used shall meet with the approval of the engineer and shall fulfill the requirements of these specifications. In no case shall aggregates containing frost or lumps of frozen materials be used.

Fine Aggregate.—Fine aggregate shall consist of sand or screenings from hard, tough, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain vegetable matter nor more than three (3) per cent of clay or loam.

Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement, and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of briquettes composed of one (1) part of the same cement and three (3) parts Standard Ottawa sand by weight. The percentage of water used in mak-

ing the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of Standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement of the American Society of Civil Engineers.

Coarse Aggregate.—Coarse aggregate shall consist of clean, durable crushed rock or gravel graded in size, free from vegetable matter, and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half (1½) inch round opening and shall range from one and one-half (1½) inch down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch.

No. 1. Aggregate for Wearing Course. No. 1 aggregate for the wearing course shall consist of clean, hard, tough, durable crushed rock or gravel, free from vegetable matter, and shall contain no soft, flat or elongated particles. It shall pass, when dry, a screen having one-half (½) inch openings and not more than ten (10) per cent shall pass a screen having one-quarter (¼) inch openings.

No. 2. Aggregate for Wearing Course. No. 2 aggregate for the wearing course shall consist of clean, hard, tough, durable crushed rock or gravel graded in size, free from vegetable matter, and shall contain no soft, flat or elongated particles. The size of No. 2 coarse aggregate shall be such as to pass a one (1) inch round opening and shall range from one (1) inch down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch and no intermediate sizes shall be removed.

3. *Mixed Aggregate.*—Crusher run stone, bank run gravel or artificially prepared mixtures of fine and coarse aggregate shall not be used.

4. *Water.*—Water shall be clean, free from oil, acid, alkali or vegetable matter.

5. *Reinforcement.*—All reinforcement shall be free from rust scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than seventy thousand (70,000) pounds per square inch and bend one hundred eighty (180) degrees around one diameter and straighten without fracture.

6. *Joint Filler.*—The filler for all transverse joints shall consist of prepared strips of fibre matrix and bitumen, or similar material of approved quality one-quarter (¼) inch in thickness. Where the joints are protected with metal plates the joint filler shall be made to conform to the cross section of the pavement and where unprotected transverse joints are used the width shall be at least one half (½) inch greater than the thickness of the pavement at any point. The filler for longitudinal joints along the curb, where a separate curb is used, shall, at the discretion of the engineer, consist of the same material as specified for the transverse joints or of bitumen which will not become soft enough to flow in hot weather or brittle in cold weather. The thickness of longitudinal joints filled with bitumen shall not be less than one-quarter (¼) inch or more than three-quarters (¾) inch.

7. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than two and one half (2½) inches in depth and not less than one-eighth (⅛) inch nor more than one-quarter (¼) inch average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of installation of joint protection plates shall be approved by the engineer.

II. GRADING.

8. *Defined.*—Grading shall include all cuts, fills, approaches and all earth or rock moving for whatever purpose where such work is an essential part of or necessary to the prosecution of the contract.

9. *Engineer's Stakes.*—Stakes will be set by the engineer for the center line, finished grades and other necessary points.

10. *Excess Material.*—Excess material shall be disposed of as directed by the engineer, the free haul not to exceed.....feet.

11. *Overhaul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of ..... cents per cubic yard for each additional ..... feet.

12. *Cuts and Fills.*—In cuts the final grade shall be obtained by rolling with a roller weighing not less than five (5) nor more than ten (10) tons. The engineer shall determine the depth of material to be thus compacted. When a fill of one (1) foot or

less is required to bring the surface to grade, all vegetable or other perishable matter shall be removed before making the fill.

Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, each of which shall extend entirely across the width to be filled. Each layer, which shall not exceed one (1) foot in depth, shall be thoroughly rolled with a roller weighing not less than five (5) nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of each layer of the fill at least twice. The use of muck, quick-sand, soft clay, spongy or perishable material, which will not consolidate under the roller, is prohibited.

When the material excavated from the cuts is not sufficient to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the fills to the proper width and grade. When the earth work is completed the cross-section of the road-bed shall conform to the cross-sectional drawings and profile attached hereto.

All approaches connecting the specified pavement with other streets or alleys, intersecting shall also be cut or filled and secured from settlement to form a slope of not more than one (1) vertical to ten (10) horizontal, as shown on the profile and plans attached hereto.

III. DRAINAGE.

13. *Drainage.*—The contractor shall construct tile or other drains as shown in the drawings attached hereto. Tile to be laid in the trench at least .....(.....) inches wide, and .....(.....) feet deep below the top of the adjacent curb. Such trench shall be back filled with crushed stone or pit run gravel with sand removed, which after light tamping shall be .....(.....) inches in depth.

14. *Catch Basins.*—All catch basins and manhole tops and all covers of openings of any kind shall be readjusted to the grade by the contractor at his expense.

IV. SUB-GRADE.

15. *Construction.*—The bottom of the excavation or the top of the fill when completed shall be known as the sub-grade and

shall be at all places true to the elevation as shown on the plans attached hereto.

The sub-grade shall be brought to a firm, unyielding surface by rolling the entire area with a self-propelled roller weighing not less than five (5) nor more than ten (10) tons, and all portions of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) pounds, the face of which shall not exceed one hundred (100) square inches in area. All soft, spongy, or yielding spots and all vegetable or other perishable matter shall be entirely removed and the space refilled with suitable material.

When considered necessary or of assistance in producing a compact solid surface, the sub-grade before being rolled shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old roadbed composed of gravel macadam, the latter shall be entirely loosened and the material spread for the full width of the roadbed and rolled. All interstices shall be filled with fine material and rolled to make a dense, tight surface of the roadbed.

16. *Acceptance.*—No concrete shall be deposited until the sub-grade is checked and accepted by the engineer.

V. FORMS.

17. *Materials.*—Where forms are required, they shall be free from warp, of sufficient strength to resist springling out of shape; wooden forms shall be of not less than two (2) inch stock.

18. *Setting.*—The forms shall be well staked or otherwise held to the established line and grades. Where the curb is to be constructed integrally with the pavement, the upper edge of the side forms shall conform to the top of the curb.

19. *Treatment.*—All mortar and dirt shall be removed from the forms that have previously been used.

VI. PAVEMENT SECTION.

20. *Width, Thickness of Concrete and Crown.*—The concrete pavement shall be .....(.....) feet wide from face to face of curb. The base of the concrete pavement shall be .....(.....) inches in depth at the center, and .....(.....) inches in depth at the

sides. The wearing course shall be of .....(..... .....) inches uniform thickness. The finished surface shall conform to the arc of a circle as shown on the plans attached hereto.

NOTE.—The minimum thickness of the concrete base shall be not less than five (5) inches and the minimum thickness of the wearing course shall not be less than two (2) inches. When pavements twenty (20) feet or less n width are to be built on approximately level ground and a flat sub-grade is to be used, sufficient fall for drainage at the sides of the pavement along the curb shall be provded by giving the roadbed the same grade as that proposed for the gutter. The crown of all pavements shall not be more than one one-hundredth (1/100) of the width, except, when deemed advisable by the engineer, the crown of a pavement built on a crowned sub-grade may be increased to one-fiftieth (1/50 of the width to provide sufficient fall for drainage along the sides of the pavement at the curb.

VII. JOINTS.

21. *Width and Location.*—Transverse joints shall be one-quarter (¼) inch in width and shall be placed across the pavement perpendicular to the center line, not more than thirty-five (35) feet apart. A longitudinal joint not less than one-quarter (¼) inch wide shall be constructed between the curb and the pavement where a separate curb is used. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to its surface.

22. *Joint Filler.*—All transverse joints shall be formed by inserting during construction and leaving in place the required thickness of prepared strips of a fibre matrix and bitumen or similar material of approved quality which shall extend through the entire thickness of the pavement and the entire thickness and height of the integral curb when the latter is specified.

Longitudinal joints along the curb, where a separate curb is specified, shall, at the discretion of the engineer, be formed in the same manner as transverse joints or constructed by filling with bitumen as before specified.

23. *Protected Joints.**—The concrete at all transverse joints

*When the specification "Protected Joints" is to be used, "Unprotected Joints" shall be omitted, and *vice versa.*

shall be protected with joint protection plates which shall be rigidly anchored to the concrete. The upper edges of the plates shall be even with each other and the adjoining surface of the concrete. All steel plates varying more than one-quarter (¼) inch from the finished surface of the concrete, as shown on the plans attached hereto, shall be ground to meet the specified requirements, or slabs in which such plates occur shall be removed and replaced with new material by the contractor at his expense.

24. *Unprotected Joints.**—All transverse joints shall extend through the entire thickness of the pavement and the filler shall project not less than one-half (½) inch above the finished surface. The concrete adjacent to these joints shall be finished with a wood float, which is divided through the center and which will permit finishing on both sides of the filler at the same time. Before the pavement is opened to traffic joint filler shall be cut off to a height of one-quarter (¼) inch above the surface of the pavement.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

25. *Measuring Materials.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A bag of Portland cement (94 lb. net) shall be considered one (1) cubic foot.

26. *Mixing.*—The materials shall be mixed in a batch mixer of approved type and mixing shall continue after all materials are in the drum for at least forty-five (45) seconds at a minimum speed of twelve (12) revolutions per minute. The drum shall be completely emptied before receiving materials for successive batches.

27. *Re-tempering.*—Re-tempering of mortar or concrete which has partially hardened; that is, remixing with or without additional materials or water, shall not be permitted.

28. *Consistency.*—The materials for the pavement shall be mixed with sufficient water to produce a concrete which will hold its shape when struck off with a template. The consistency shall

*When the specification "Protected Joints" is to be used, "Unprotected Joints" shall be omitted, and *vice versa*.

not be such as to cause a separation of the mortar from the aggregate in handling.

29. *Cement Required.*—A cubic yard of concrete base in place shall contain at least one and four-tenths (1.4) barrels of cement.) A cubic yard of "No. 1 Mix Wearing Course" in place shall contain at least two and ninety-seven hundredths (2.97) barrels of cement and a cubic yard of "No. 2 Mix Wearing Course" in place shall contain at least two and one-tenth (2.1) barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto, with the amounts actually used in each section of concrete (including integral curbs when used) between successive transverse joints, as determined by actual count of the number of bags of cement used in each section. If the amount of cement used in any three (3) adjacent sections (between transverse joints) is less by more than two (2) per cent of if the amount of cement used in any one section is less by more than five (5) per cent of the amount hereinbefore required, the contractor shall remove all such sections and replace the same with new materials, according to these specifications, at his expense.

IX. REINFORCING.

30. *Reinforcing.*—Concrete pavements twenty (20) feet or more in width shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement shall amount to at least 0.038 square inch per foot and the cross-sectional area of reinforcing metal, which is perpendicular to the center line of the pavement, shall amount to at least 0.049 square inch per foot.

Reinforcing metal shall be placed between base and wearing course and shall be not less than two (2) inches from the finished surface of the pavement and otherwise shall be placed as shown on the drawings. The reinforcing metal shall extend to within two (2) inches of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) inches when the lap is made perpendicular to the center line of the pavement and not less than one (1) foot when the lap is made parallel to the center line of the pavement.

X. PLACING CONCRETE.

CONCRETE FOR BASE.

31. *Proportions.*—The concrete shall be mixed in the proportions of one (1) bag of Portland cement to not more than two and one-half (2½) cubic feet of fine aggregate, and not more than four (4) cubic feet of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the coarse aggregate.

32. *Placing Aggregate.*—Immediately prior to placing the concrete, the subgrade shall be brought to an even surface. The surface of the subgrade shall be thoroughly wet, but shall show no pools of water when the concrete is placed.

After mixing, the concrete shall be deposited rapidly upon the subgrade, to the required depth and for the entire width of the pavement in successive batches and in a continuous operation without the use of intermediate forms or bulkheads between expansion joints.

The concrete shall be brought to an even surface, the thickness of the wearing course, below the established grade of the pavement. Workmen shall not be allowed to walk on the freshly laid concrete, and if sand or dust collects on the base it shall be removed before the wearing course is applied. The reinforcing metal shall be placed upon and slightly pressed into the concrete base immediately after it is placed.

In case of a breakdown concrete shall be mixed by hand to complete the section or an intermediate joint placed, as hereinbefore specified at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

CONCRETE FOR WEARING COURSE.

33. *Proportions for Mixture No. 1*.*—The concrete for the wearing course shall be mixed in the manner hereinbefore specified in the proportions of one (1) bag of cement to not more than one (1) cubic foot of fine aggregate, and not more than one and

*When Article No. 33 is specified, Article No. 34 should be omitted, and *vice versa.*

one-half (1½) cubic feet of "No. 1 Aggregate for Wearing Course," and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of the "No. 1 Aggregate for Wearing Course."

34. *Proportions for Mixture No. 2**.—The concrete for the wearing course shall be mixed in the manner hereinbefore specified in the proportions of one (1) bag of Portland cement to not more than one and one-half (1½) cubic feet of fine aggregate, and not more than two and one-half (2½) cubic feet of "No. 2 Aggregate for Wearing Course," hereinbefore specified, and in no case shall the volume of the fine aggregate be less than one-half (½) the volume of "No. 2 Aggregate for Wearing Course."

35. *Placing.*—The wearing course shall be placed immediately after mixing, and in no case shall more than forty-five (45) minutes elapse between the time that the concrete for the base has been mixed and the time the wearing course is placed.

36. *Finishing.*—The wearing course shall be struck off for the entire width of the pavement and from back to back of integral curbs when used, by means of a template or strike board. Any holes left by removing any material or device used in constructing the joint shall be immediately filled with mortar composed of one (1) part of cement and two (2) parts of fine aggregate. Concrete adjoining metal protection plates at transverse joints shall be dense in character, and shall be given a smooth finish with a steel trowel for a distance of six (6) inches on each side of the joints.

After being brought to the established grade with the template or strikeboard, the concrete shall be finished from a suitable bridge, no part of which shall come in contact with the concrete. If approved by the engineer, the contractor may use a mechanical striking and finishing machine. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter (¼) inch from the true shape.

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*When Article No. 33 is specified, Article No. 34 should be omitted, and *vice versa*.

XI. INTEGRAL CURB.

37. *Construction.*—An integral curb shall be constructed, as shown on the attached drawings, to the established grade and in a continuous line on each side of the street..... (.....) feet from and parallel with the center line thereof, except at all intersections of streets, alleys and driveways where it shall be returned to the street line, and at these intersections it shall be rounded to such a radius as the engineer may direct.

The concrete for that portion of the integral curbs above the base shall be of the same materials and proportions as that specified for the wearing course.

After striking off the pavement, the concrete for that portion of the integral curbs above the gutter line shall be immediately deposited.

The top and inside surface of integral curbs shall be given a smooth finish and completed with the pavement to the point of stopping each day's work.

NOTE.—Article No. 37 to be omitted if separate curb is specified.

XII. PROTECTION.

38. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth or other approved covering is placed. As soon as it can be done without damaging the concrete, the surface of the pavement shall be covered with not less than two (2) inches of earth or other material approved by the engineer, which cover shall be kept wet for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concrete shall be protected by canvas until such covering can be placed.

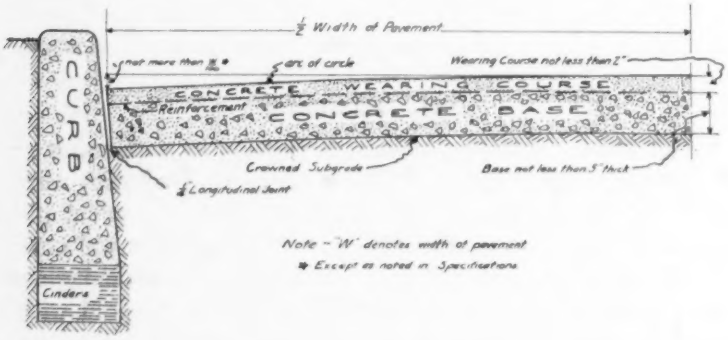
Under the most favorable conditions for hardening in hot weather, the pavement shall be closed to traffic for at least fourteen (14) days, and in cool weather for an additional time, to be determined by the engineer.

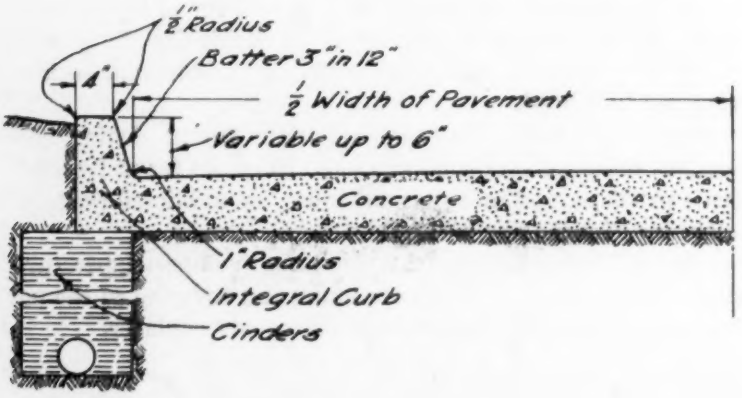
At the season of the year when the average temperature is below 50 degrees Fahrenheit, sprinking and covering of the pavement may be omitted at the direction of the engineer.

The contractor shall erect and maintain suitable barriers to protect the concrete from traffic and any part of the pavement damaged from traffic or other causes, occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and disposed of as directed by the engineer.

39. *Temperature Below 35 Degrees Fahrenheit.*—Concrete shall not be mixed or deposited when the temperature is below freezing.

If, at any time during the progress of the work the temperature is, or, in the opinion of the engineer, will, within twenty-four (24) hours drop to 35 degrees Fahrenheit, the water and aggregates shall be heated, and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen subgrade.





AMERICAN CONCRETE INSTITUTE

Founded 1905 and Incorporated 1906, as
NATIONAL ASSOCIATION OF CEMENT USERS
Charter Amended July 2, 1913.

PHILADELPHIA, PA.

PROPOSED STANDARD SPECIFICATIONS FOR ONE-COURSE CONCRETE ALLEY PAVEMENTS

I. Materials.

1. *Cement.*—The cement shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society. (Standard No. 1.)

2. *Aggregates.*—Before delivery on the job, the contractor shall submit to the engineer a fifty (50) lb. sample of each of the fine and coarse aggregates proposed for use. These samples shall be tested and if found to pass the requirements of the specifications similar material shall be considered as acceptable for the work. All aggregates used shall meet with the approval of the engineer and shall fulfill the requirements of these specifications. In no case shall aggregates containing frost or lumps of frozen materials be used.

(*a*) *Fine Aggregate.*—Fine aggregate shall consist of sand or screenings from hard, tough, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent shall pass a sieve having one hundred (100)

meshes per linear inch. Fine aggregate shall not contain vegetable matter nor more than three (3) per cent of clay or loam.

Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of briquettes composed of one (1) part of the same cement and three (3) parts Standard Ottawa sand by weight. The percentage of water used in mixing the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of Standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement of the American Society of Civil Engineers.

(*b*) *Coarse Aggregate.*—Coarse aggregate shall consist of clean, hard, tough, durable crushed rock or gravel graded in size, free from vegetable matter, and shall contain no soft, flat or elongated particles. The size of the coarse aggregate shall be such as to pass a one and one-half ($1\frac{1}{2}$) in. round opening and shall range from one and one-half ($1\frac{1}{2}$) in. down, not more than five (5) per cent passing a screen having four (4) meshes per linear inch, and no intermediate sizes shall be removed.

(*c*) *Mixed Aggregate.*—Crusher run stone, bank-run gravel or artificially prepared mixtures of fine and coarse aggregate shall not be used.

3. *Water.*—Water shall be clean, free from oil, acid, alkali or vegetable matter.

4. *Reinforcement.*—All reinforcement shall be free from rust-scale, paint or coatings of any character which will tend to destroy the bond. All reinforcement shall develop an ultimate tensile strength of not less than seventy thousand (70,000) lb. per sq. in. and bend one hundred and eighty (180) degrees around one diameter and straighten without fracture.

5. *Joint Filler.*—The filler for all transverse joints shall consist of prepared strips of fibre matrix and bitumen or similar material of approved quality one-quarter ($\frac{1}{4}$) in. in thickness. Where the joints are protected with metal plates the joint filler shall be made to conform to the cross-section of the pavement and where unprotected transverse joints are used the width shall be at least one-half ($\frac{1}{2}$) in. greater than the thickness of the pave-

ment at any point. The filler for longitudinal joints shall, at the discretion of the engineer, consist of the same material as specified for the transverse joints or of bitumen which will not become soft enough to flow in hot weather or brittle in cold weather. The thickness of longitudinal joints filled with bitumen shall not be less than one-quarter ($\frac{1}{4}$) in. or more than three-quarter ($\frac{3}{4}$) in.

6. *Joint Protection Plates.*—Soft steel plates for the protection of the edges of the concrete at transverse joints shall be not less than two and one-half ($2\frac{1}{2}$) in. in depth and not less than one-eighth ($\frac{1}{8}$) nor more than one-quarter ($\frac{1}{4}$) in. average thickness. The plates shall be of such form as to provide for rigid anchorage to the concrete. The type and method of installation of joint protection plates shall be approved by the engineer.

II. GRADING.

7. *Defined.*—Grading shall include all cuts, fills, approaches and all earth or rock moving for whatever purpose where such work is an essential part of or necessary to the prosecution of the contract.

8. *Engineer's Stakes.*—Stakes will be set by the engineer for the center line, finished grades and other necessary points.

9. *Excess Material.*—Excess material shall be disposed of as directed by the engineer, the free haul not to exceed .....ft.

10. *Over-Haul.*—Materials hauled a greater distance than the free haul from the place of excavation shall be paid for at the rate of .... cents per cu. yd. for each additional .....ft.

11. *Cuts and Fills.*—In cuts the final grade shall be obtained by rolling with a roller weighing not less than five (5) nor more than ten (10) tons. The engineer shall determine the depth of material to be thus compacted. When a fill of one (1) ft. or less is required to bring the surface to grade, all vegetable or other perishable matter shall be removed before making the fill.

Embankments shall be formed of earth or other approved materials and shall be constructed in successive layers, each of which shall extend entirely across the width to be filled. Each layer, which shall not exceed one (1) ft. in depth, shall be thoroughly rolled with a roller weighing not less than five (5) nor more than ten (10) tons before the succeeding layer is placed. The roller shall pass over the entire area of each layer of the fill at least

twice. The use of muck, quicksand, soft clay, spongy or perishable material, which will not consolidate under the roller, is probhited

When the material excavated from the cuts is not sufficiedt to make the fills shown on the plans, the contractor shall furnish the necessary extra material to bring the ffils to the proper width and grade. When the earth work is completed the cross-section of the roadbed shall conform to the cross-sectional drawings and profile attached hereto.

All approaches connecting the specified pavement with other streets or alleys intersecting, shall also be cut or filled, and secured from settlement, to form a slope of not more than one (1) vertical to ten (10) horizontal, as shown on the profile and plans attached hereto.

III. DRAINAGE.

12. *Drainage.*—The contractor shall construct tile or other drains as shown in the drawings attached hereto. Tile to be laid in the trench at least ..... (....) in. wide, and ..... (....) ft. deep below the established grade of the pavement. Such trench shall be back filled with crushed stone or pit run gravel with sand removed, which after light tamping shall be ..... (....) in. in depth.

13. *Catch Basins.*—All catch basins and manhole tops and all covers of openings of any kind shall be readjusted to the grade by the contractor at his expense.

IV. SUB-GRADE.

14. *Construction.*—The bottom of the excavation or the top of the fill when completed shall be known as the sub-grade and shall be at all places true to the elevation as shown on the plans attached hereto.

The sub-grade shall be brought to a firm, unyielding surface by rolling the entire area with a self-propelled roller weighing not less than five (5) nor more than ten (10) tons, and all portions of the surface of the sub-grade which are inaccessible to the roller shall be thoroughly tamped with a hand tamp weighing not less than fifty (50) lb., the face of which shall not exceed one hundred (100) sq. in. in area. All soft, spongy, or yielding spots and all vegetable or other perishable matter, shall be entirely removed and the space refilled with suitable material.

When considered necessary or of assistance in producing a compact, solid surface, the sub-grade before being rolled shall be well sprinkled with water.

When the concrete pavement is to be constructed over an old pavement composed of gravel or macadam, the latter shall be entirely loosened and the material spread for the full width of the pavement and rolled. All interstices shall be filled with fine material and rolled to make a dense, tight surface.

15. *Acceptance.*—No concrete shall be deposited until the sub-grade is checked and accepted by the engineer.

V. FORMS.

16. *Materials.*—Metal or wooden forms shall be free from warp, of sufficient strength to resist springing out of shape, and shall be equal in width to the thickness of the pavement at the edges. Wooden forms shall be of not less than two (2)-in. stock. Where the pavement is laid adjacent to buildings, fences or other structures, the side forms may be omitted at the direction of the engineer, but a joint must be constructed as hereinafter specified between the pavement and such structure.

17. *Setting.*—The forms shall be well staked or otherwise held to the established line and grades, and the upper edge shall conform to the established grade of the alley.

18. *Treatment.*—All mortar and dirt shall be removed from the forms that have previously been used.

VI. PAVEMENT SECTION.

19. *Width, Thickness of Pavement and Cross-Section.*—The width of the pavement shall be ..... (....) ft., ... (....) in. and not less than six (6) in. uniform thickness. In cross-section the finished surface shall have the uniform pitch toward the center line, except the center twelve (12) in. shall be rounded to the arc of a circle which is tangent to the surface of the concrete at points six (6) in. on each side of the center line, as shown in the plans attached hereto. The pitch shall not exceed one-fiftieth ($\frac{1}{50}$) of the width of the pavement.

VII. JOINTS.

20. *Width and Location.*—Transverse joints shall be one-quarter ($\frac{1}{4}$) in. in width and shall be placed across the pavement

perpendicular to the center line, not more than thirty-five (35) ft. apart. When the pavement is laid adjacent to buildings, fences, or other structures, a longitudinal joint shall, at the discretion of the engineer, be constructed. All joints shall extend through the entire thickness of the pavement and shall be perpendicular to the surface.

21. *Joint Filler.*—All transverse joints shall be formed by inserting during construction and leaving in place the required thickness of prepared strips of fibre matrix and bitumen, or other similar material of approved quality, which shall extend through the entire thickness of the pavement.

Longitudinal joints shall, at the discretion of the engineer, be formed in the same manner as transverse joints or constructed by filling with bitumen as before specified.

22. *Protected Joints.*—The concrete at transverse joints shall be protected with joint protection plates which shall be rigidly anchored to the concrete. The upper edges of the plates shall be even with each other and the adjoining surface of the concrete. All steel plates varying more than one-quarter ($\frac{1}{4}$) in. from the finished surface of the concrete, as shown on the plans attached hereto, shall be ground to meet the specified requirements, or slabs in which such plates occur shall be removed and replaced with new material by the contractor at his expense.

23. *Unprotected Joints.*—All transverse joints shall extend through the entire thickness of the pavement and the filler shall project not less than one-half ($\frac{1}{2}$) in. above the finished surface. The concrete adjacent to these joints shall be finished with a wood float, which is divided through the center and which will permit finishing on both sides of the filler at the same time. Before the pavement is opened to traffic joint filler shall be cut off to the height of one-quarter ($\frac{1}{4}$) in. above the surface of the pavement.

NOTE.—When the specification "Protected Joints" is to be used, "Unprotected Joints" should be omitted, and vice versa.

VIII. MEASURING MATERIALS AND MIXING CONCRETE.

24. *Measuring Materials.*—The method of measuring the materials for the concrete, including water, shall be one which will insure separate and uniform proportions of each of the materials at all times. A sack of Portland cement (94 lb. net) shall be considered one (1) cu. ft.

25. *Mixing.*—The materials shall be mixed in a batch mixer of approved type and mixing shall continue after all materials are in the drum for at least forty-five (45) seconds at a minimum speed of twelve (12) revolutions per minute. The drum shall be completely emptied before receiving materials for successive batches.

26. *Retempering.*—Retempering of mortar or concrete which has partially hardened; that is, remixing with or without additional materials or water, shall not be permitted.

27. *Proportions.*—The concrete shall be mixed in the proportions of one (1) sack of Portland cement to not more than two (2) cu. ft. of fine aggregate and not more than three (3) cu. ft. of coarse aggregate, and in no case shall the volume of the fine aggregate be less than one-half ($\frac{1}{2}$) the volume of the coarse aggregate.

A cubic yard of concrete in place, shall contain not less than one and seven-tenths (1.7) barrels of cement.

The engineer shall compare the calculated amount of cement required according to these specifications and plans attached hereto with the amounts actually used in each section of concrete between successive transverse joints, as determined by actual count of the number of sacks of cement used in each section. If the amount of cement used in any three (3) adjacent sections (between transverse joints) is less by more than two (2) per cent, or if the amount of cement used in one section is less by more than five (5) per cent of the amount hereinbefore required, the contractor shall remove all such sections and replace the same with new materials, according to these specifications, at his expense

28. *Consistency.*—The materials shall be mixed with sufficient water to produce a concrete which will hold its shape when struck off with a template. The consistency shall not be such as to cause a separation of the mortar from the coarse aggregate in handling.

IX. REINFORCING.

29. *Reinforcing.*—Concrete pavements twenty (20) ft. or more in width, shall be reinforced. The cross-sectional area of the reinforcing metal running parallel to the center line of the pavement shall amount to at least 0.038 sq. in. per ft. and the cross-sectional area of reinforcing metal, which is perpendicular to the center line of the pavement, shall amount to at least 0.049 sq. in. per ft.

Reinforcing metal shall not be placed less than two (2) in. from the finished surface of the pavement and otherwise shall be placed as shown on the drawings attached hereto. The reinforcing metal shall extend to within two (2) in. of all joints, but shall not cross them. Adjacent widths of fabric shall be lapped not less than four (4) in. when the lap is made perpendicular to the center line of the pavement and not less than one (1) ft. when the lap is made parallel to the center line of the pavement.

X. PLACING CONCRETE.

30. *Placing Concrete.*—Immediately prior to placing the concrete, the sub-grade shall be brought to an even surface. The surface of the sub-grade shall be thoroughly wet but shall show no pools of water when the concrete is placed.

After mixing, the concrete shall be deposited rapidly upon the sub-grade, to the required depth and for the entire width of the pavement in successive batches and in a continuous operation without the use of intermediate forms or bulk heads between expansion joints.

In case of a breakdown concrete shall be mixed by hand to complete the section or an intermediate transverse joint placed as hereinbefore specified at the point of stopping work. Any concrete in excess of that needed to complete a section at the stopping of work shall not be used in the work.

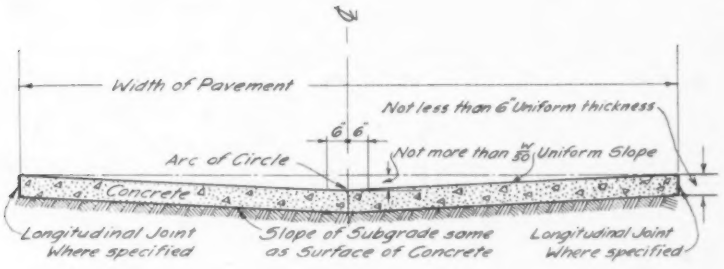
31. *Finishing.*—The surface of the concrete shall be struck off by means of a template or strikeboard. Any holes left by removing any material or device used in constructing the joint shall be immediately filled with mortar composed of one (1) part cement and two (2) parts of fine aggregate. Concrete adjoining metal protection plates at transverse joints shall be dense in character and shall be given a smooth finish with a steel trowel for a distance of six (6) in. on each side of the joints.

After being brought to the established grade with the template or strikeboard, the concrete shall, where possible, be finished from a suitable bridge, no part of which shall come in contact with the concrete. The concrete shall be finished with a wood float in a manner to thoroughly compact it and produce a surface free from depressions or inequalities of any kind. The finished surface of the pavement shall not vary more than one-quarter ($\frac{1}{4}$) in. from the true shape.

XI. PROTECTION.

32. *Curing and Protection.*—Excepting as hereinafter specified, the surface of the pavement shall be sprayed with water as soon as the concrete is sufficiently hardened to prevent pitting, and shall be kept wet until an earth or other approved covering is placed. As soon as it can be done without damaging the concrete the surface of the pavement shall be covered with not less than two (2) in. of earth or other material approved by the engineer, which cover shall be kept wet for at least ten (10) days. When deemed necessary or advisable by the engineer, freshly laid concrete shall be protected by canvas until such covering can be placed.

Under the most favorable conditions for hardening in hot weather, the pavement shall be closed to traffic for at least fourteen



Note:- "W" denotes width of pavement

(14) days and in cool weather for an additional time, to be determined by the engineer.

At the season of the year when the average temperature is below fifty (50) degrees Fahrenheit, sprinkling and covering of the pavement may be omitted at the direction of the engineer.

The contractor shall erect and maintain suitable barriers to protect the concrete from traffic and any part of the pavement damaged from traffic or other causes, occurring prior to its official acceptance, shall be repaired or replaced by the contractor at his expense, in a manner satisfactory to the engineer. Before the pavement is thrown open to traffic the covering shall be removed and disposed of as directed by the engineer.

33. *Temperature Below 35 Degrees Fahrenheit.*—Concrete

shall not be mixed or deposited when the temperature is below freezing.

If, at any time during the progress of the work the temperature is, or in the opinion of the engineer, will, within twenty-four (24) hours drop to thirty-five (35) degrees Fahrenheit, the water and aggregates shall be heated, and precautions taken to protect the work from freezing for at least ten (10) days. In no case shall concrete be deposited upon a frozen sub-grade.

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TEST OF A REINFORCED CONCRETE SLAB.

By E. B. McCormick.*

Because of the uncertainty existing among bridge designers and concrete engineers regarding the distribution throughout a concrete slab of the effects of loads, it has been the custom to use a width of from 1 to 4 ft. as a repeating section. It has been recognized that these widths could probably be increased if more were learned regarding the distribution of the stresses. About three years ago the U. S. Office of Public Roads undertook a series of experiments to determine, if possible, the effective width of reinforced concrete slabs under various conditions of loading. The earlier tests were made on slabs 7 by 9 ft. using a span of 6 ft. Some interesting results were obtained, but it was apparent that the size of the slab must be increased if definite, corroborative results were to be secured.

In the summer of 1914, a slab was constructed 12 in. thick by 32 ft. wide, and with a span of 16 ft. The reinforcement amounted to 0.75 per cent and consisted of $\frac{3}{4}$-in. square bars, spaced $7\frac{1}{4}$ in. on centers. The load was applied by means of a hydraulic jack having a capacity of 150 tons. The intensity of the load was measured by the deflection of a chrome nickel alloy steel bar 5 x 7 in. The bar was placed in the line of application of the load. The steel from which the bar was rolled had a tensile strength of 250,000 lb. per sq. in. and an elastic limit of 200,000 lb. per sq. in. The deflection of the steel beam was calibrated on a 200,000-lb. Riehlé testing machine. The apparatus arranged for applying a four-point load is shown in Fig. 1.

In this first test no attempt was made to determine the effect of cross reinforcing, the slippage of the steel, or the fibre stresses along the bottom of the slab. The slab was designed for a fibre stress of 650 lb. per sq. in. along the top surface. Cylinders 8 x 16 in. cast from the same mix showed a modulus of elasticity of 2,900,000 at an age of 6 weeks.

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The deformations along the top surface were measured at 20-in. intervals by means of a Berry strain gage. From these deformations the fibre stresses were calculated by the formula: $x = dE = RCE$, where R is the reading of the dial, and C the constant of the strain gage, in this case 0.01.

The first readings were taken with center loads of 25,000, 30,000, and 32,500 lb. per sq. in. In Fig. 2 are shown the lines of equal stress resulting from a center load of 30,000 lb. The cross-hatched portion of this diagram shows the intensity of the

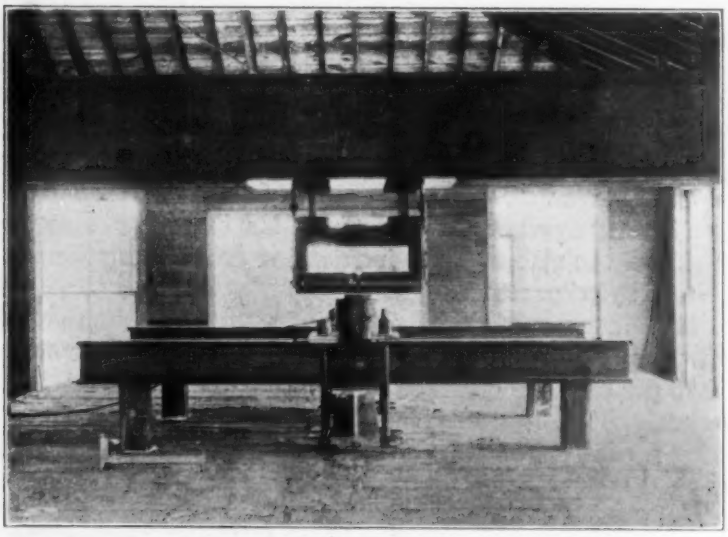

FIG. 1.—APPARATUS FOR APPLYING FOUR-POINT LOADS.

top fibre stress along a section passed through the point of application of the load and parallel to the supports.

The effective width of slab under each of the three loads is shown on Fig. 3. This "effective width" is considered to be the width of a slab, which, if subjected to a load of a certain magnitude, uniformly distributed along the top fibre of the center section, will have the same maximum outside fibre stress and the same total fibre stress as the tested slab showed under the concentrated load of that magnitude. It will be noted from the diagrams in Fig. 3 that the effective width is the same for loads of

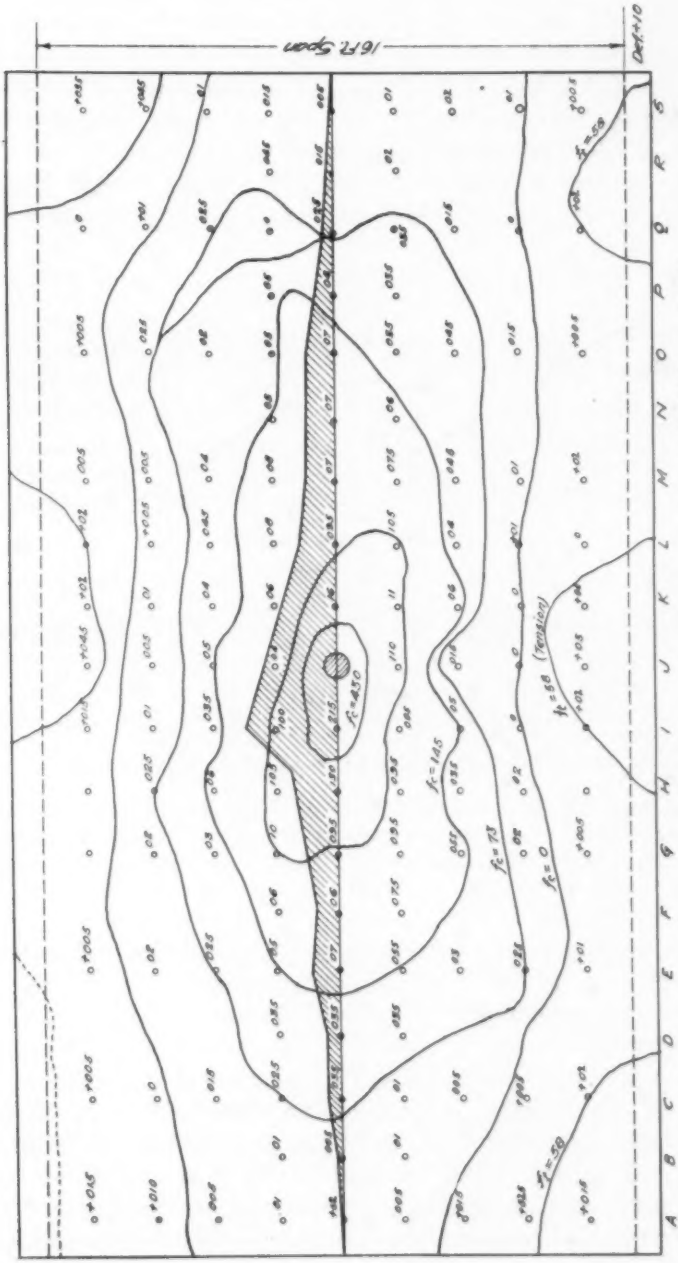

FIG. 2.—LINES OF EQUAL STRESS. CENTRAL LOADING OF 30,000 LB. TOTAL.

different magnitudes; *i. e.*, the effective width of a slab is apparently independent of the magnitude of the load.

Fig. 4 shows the line of equal stress, or equal deformation, for a two-point load of 80,000 lb.; and the upper and lower diagrams on Fig. 5, the fibre stresses along the center section parallel to the support for two-point loads of 40,000 lb. and 80,000 lb., respectively. This two-point load was applied along the

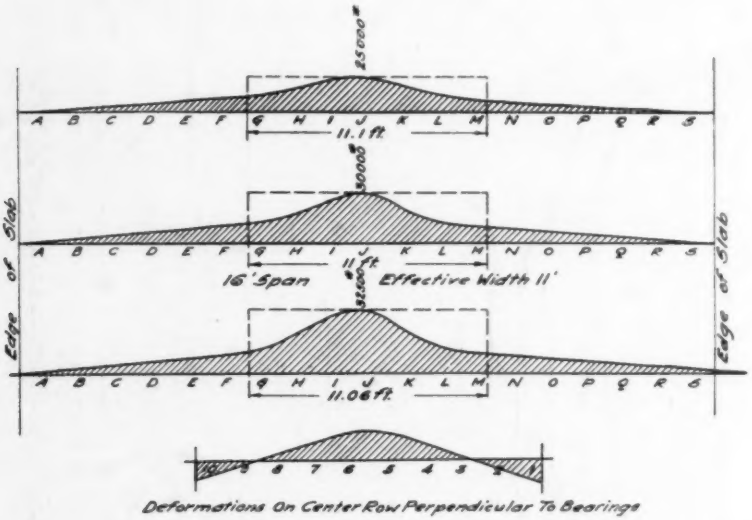

FIG. 3.—DEFORMATIONS ON CENTER LINE OF SLAB NO. 836. SPAN, 16 FT.; WIDTH, 30 FT.; EFFECTIVE WIDTH, 11 FT.; EFFECTIVE DEPTH, 10.5 IN. (CONCENTRATED LOADS OF 25,000, 30,000 AND 32,500 LB. CENTER LOADING).

center line parallel to the supports, and equidistant from the center of width of the slab. The points of application were 6 ft. apart. The maximum total load was 80,000 lb. or 40,000 lb. on each point.

In the hope of securing conditions somewhat similar to those met with in the case of a bridge carrying a traction engine, road roller, or loaded truck, a four-point load was applied, as shown in Fig. 1. The total maximum load in this case was 100,000 lb. The points were arranged symmetrically about the center, 8 ft. apart longitudinally, and 5 ft. transversely. The equal stress line

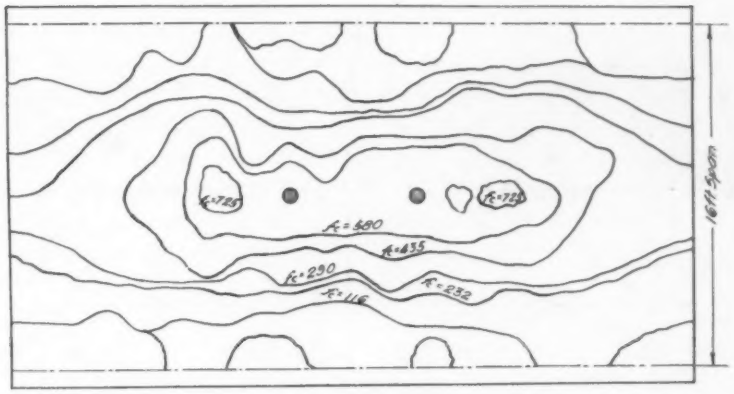

FIG. 4.—EQUAL STRESS LINES ON SLAB NO. 835. TOTAL LOAD OF 80,000 LB. ON TWO POINTS.

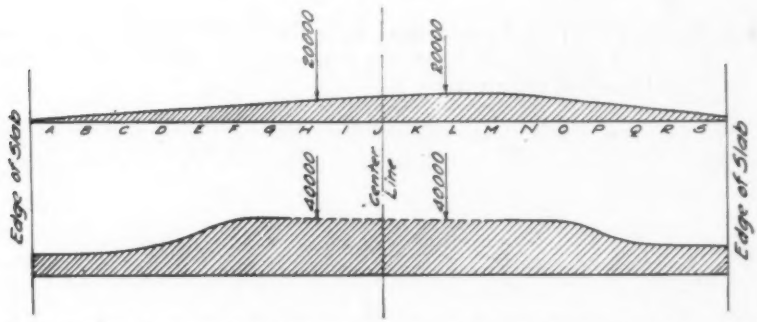

FIG. 5.—FIBRE STRESSES ALONG CENTER SECTION FOR TWO-POINT LOADINGS.

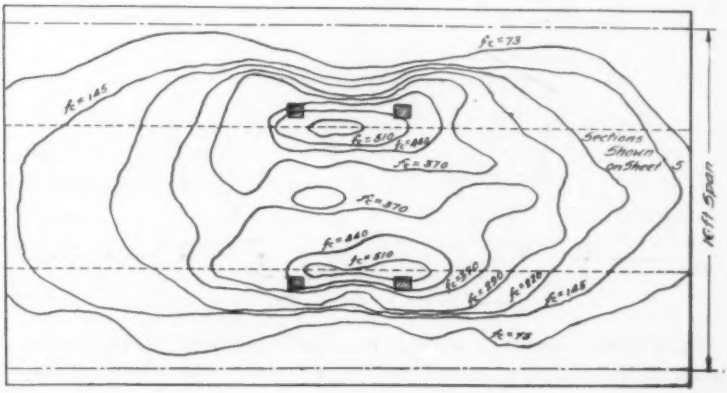

FIG. 6.—EQUAL STRESS LINES ON SLAB NO. 835. TOTAL LOAD 100,000 LB. ON FOUR POINTS.

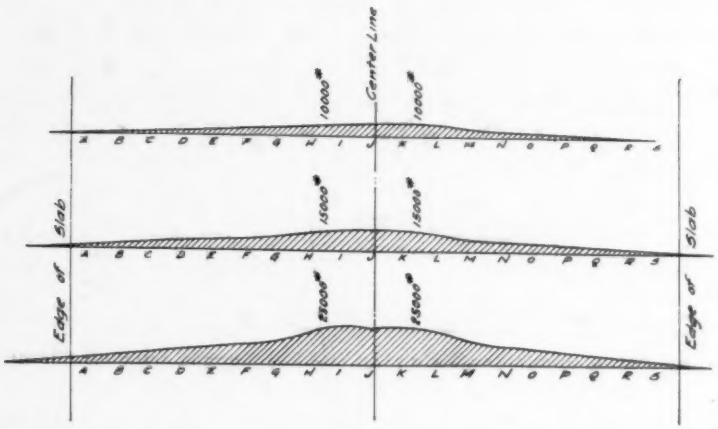

FIG. 7.—DEFORMATIONS OF CONCRETE ALONG DOTTED LINES AS SHOWN ON FIG. 6. AVERAGE OF 3–4 AND 7–8 ARE PLOTTED. TOTAL LOAD ON SLAB 100,000 LB. ON FOUR POINTS.

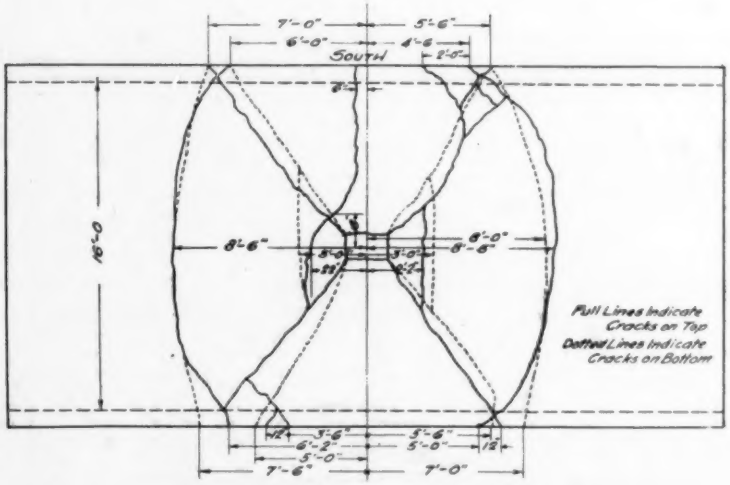

FIG. 8.—LOCATION OF CRACKS IN SLAB NO. 835 WHEN TESTED TO DESTRUCTION. TOTAL LOAD 119,000 LB. ON CENTRAL PLATE 12 X 24 IN.

diagram for this load is shown in Fig. 6, and the top fibre stresses in the lower diagram in Fig. 7. The upper and middle diagrams in this figure show the fibre stresses for total loads of 40,000 lb. and 60,000 lb., respectively.

On November 16, 1914, this slab was tested to destruction in the presence of some fifty visiting engineers. The load was applied at the center on a plate 12 x 24 in. The object in using this plate instead of the 6-in. cylinder used in previous tests was to avoid punching a hole through the slab. The load was applied steadily until failure, observations of cracks and other phenomena being noted as work progressed. A total load of 119,000 lb. was applied. Failure was by a combination of tension in the bottom and compression in the top fibres. The width of slab over which failure extended was about 17 ft. The location of the cracks is shown in Fig. 8. The full lines show those formed on the top; the dotted lines, those on the bottom. It will be observed that these cracks are contained within an approximate circle of 17 ft. diameter.

The data obtained from the tests of one slab do not, of course, warrant the drawing of final conclusions, but they are of particular interest in that they confirm the results indicated in the tests of the smaller slabs.

It is the intention to continue the work until a sufficient number of slabs have been tested to warrant the deduction of definite laws relating to the distribution of stresses in loaded concrete slabs. There is now under construction a thinner slab of the same area, per cent of reinforcement and proportions of materials. The tests on this slab will include measurements to determine fibre stresses on the bottom of the slab and also the slippage of the reinforcement. The object in using a thinner slab for the second test is to determine, if possible, what effect the thickness of the slab has on the effective width.

Arrangements are being made to secure the co-operation of interested engineers, through an advisory committee that is to be appointed to confer with the engineers of the Office of Public Roads in laying out the work to be done in the future. It is hoped that colleges and experiment stations will carry on series of tests of this nature, the results of which may be correlated with those obtained by the Office of Public Roads.

AMERICAN CONCRETE INSTITUTE

Founded 1905 and Incorporated 1906, as
NATIONAL ASSOCIATION OF CEMENT USERS
Charter Amended July 2, 1913.

PHILADELPHIA, PA.

PROPOSED REVISED RECOMMENDED PRACTICE FOR CONCRETE ARCHITECTURAL STONE, BUILDING BLOCK AND BRICK.

This recommended practice is intended to cover general requirements for the manufacture and testing of concrete architectural stone, building block and brick.

Materials.

1. The *cement* shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society. (Standard No. 1.)

2. (*a*) *Fine Aggregate.*—Fine aggregate shall consist of sand or screenings from hard, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent should pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent should pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate should not contain vegetable matter nor more than three (3) per cent of clay or loam. In no case should fine aggregate containing frost or lumps of frozen material be used.

Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement, and three (3) parts fine aggregate,

by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of briqettes composed of one (1) part of the same cement and three (3) parts standard Ottawa sand by weight. The percentage of water used in making the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement, of the American Society of Civil Engineers.

(*b*) *Coarse Aggregate.*—Coarse aggregate should consist of clean, hard, durable crushed rock or gravel graded in size, free from vegetable matter, and should contain no soft, flat or elongated particles. In no case should coarse aggregate containing frost or lumps of frozen material be used. The maximum size of the coarse aggregate shall be one-half ($\frac{1}{2}$) the thickness of the minimum wall section. Material should range from the maximum size down to not more than five (5) per cent passing a screen having four (4) meshes per linear inch.

(*c*) *Natural Mixed Aggregate,* such as bank-run gravel or artificially prepared mixtures of fine and coarse aggregate such as crusher-run stone, should not be used but should be screened over a one-quarter ($\frac{1}{4}$) in. screen and remixed to agree with the proportions as specified.

3. When *color* is required only the most permanent and durable mineral colors should be used, and same should be considered as aggregate.

4. *Water* should be clean, free from oil, acids, strong alkalis or vegetable matter. An automatic measuring device should be used to measure the amount of water used in each batch of concrete, and after the desired consistency has been determined, this amount should be used in each batch until working conditions demand a change.

PROPORTIONS.

5. For *architectural stone* without mortar face, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate and three (3) cubic feet of coarse aggregate. For architectural stone with mortar

face, the backing of concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two and one-half ($2\frac{1}{2}$) cubic feet of fine aggregate and four (4) cubic feet of coarse aggregate; the mortar surface should be mixed in proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate.

For *concrete block* containing no coarse aggregate, the concrete should be mixed in proportions of one (1) bag of Portland cement to not more than three (3) cubic feet of fine aggregate. For concrete block with or without mortar face, in which coarse aggregate is used, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two and one-half ($2\frac{1}{2}$) cubic feet of fine aggregate and four (4) cubic feet of coarse aggregate. Facing for concrete block should be mixed in proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate.

For *brick* in which no coarse aggregate is used, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than three (3) cu. ft. of fine aggregate. For brick in which coarse aggregate is used, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two (2) cubic feet of fine aggregate and three (3) cu. ft. of coarse aggregate.

A bag of Portland cement, ninety-four (94) lb. net, shall be considered one (1) cu. ft. The method of measuring the materials for the concrete shall be one which will insure separate and uniform proportions of each of the materials at all times. When cement in bulk is used the cement shall be accurately measured in such manner as will insure that the measured amount of cement used as the equivalent of one (1) bag shall be ninety-four (94) lb.

MIXING.

6. *Mixing.*—The materials should be mixed to the desired consistency in a batch mixer of approved type, and the mixing should continue for at least one minute after all materials, including water, are in the mixer.

7. *Retempering* of mortar or concrete which has partially hardened, that is, remixing with additional materials or with water, should not be permitted.

8. *Consistency.*—For *architectural stone,* concrete should be mixed wet enough that water will freely flush to the surface with slight tamping.

For *building block* made by hand or power tamping, concrete should be mixed as wet as practicable to use in the ordinary make of block machine and allow immediate removal of the finished block from the mold. For concrete block made under pressure, concrete should be mixed wet enough that a slight excess of water will be ejected from the block when pressure is applied. For concrete block made by the wet process, concrete should be wet enough to immediately fill all parts of the mold without tamping, but not wet enough to cause the mortar to separate from the coarse aggregate.

For *brick,* concrete should be mixed as wet as possible to use in the ordinary machines in which brick are made by hand or power tamping, or by the application of pressure. Sufficient water should always be used to slightly flush to the surface under tamping or pressure.

WINTER WORK.

9. No architectural stone, building block or brick should be made when the temperature of the atmosphere surrounding the machine or mold is lower than fifty (50) degrees Fahrenheit. Aggregates and water should be heated when the temperature of either is lower than fifty (50) degrees Fahrenheit.

CURING.

10. *Steam Curing.*—Immediately after completing the manufacture of architectural stone, building block and brick, they should be placed in a curing chamber where the temperature is not lower than fifty (50) degrees Fahrenheit, and protected from drafts of air and from all exposure which will tend to cause evaporation of moisture from the concrete. Within twelve (12) hours after removing architectural stone, building block and brick from the place of manufacture, the temperature in the curing chamber should be raised to between one hundred (100) and one hundred thirty (130) degrees Fahrenheit, and an atmosphere saturated with water vapor maintained by introducing water vapor from a boiler into the curing chamber. This water vapor should be introduced through a perforated pipe laid perforations down in a trough of water in the floor of the curing chamber.

(*a*) When the outside temperature during the daytime does not fall below fifty (50) degrees Fahrenheit, architectural stone, building block and brick shall be steam cured, as described above, for not less than forty-eight (48) hours, after which they may be removed from the curing chamber and piled in the yard. They shall then be sprinkled not less than three (3) times daily for seven (7) days. They may be used after having laid in the yard not less than (14) days.

(*b*) When the temperature of the outside atmosphere falls below fifty (50) degrees Fahrenheit during the daytime, architectural stone, building block and brick shall be steam cured for not less than ninety-six (96) hours, after which they may be piled in the yard. They need not receive any further treatment but shall remain in the yard for not less than fourteen (14) days.

In the steam curing process, two requirements should be observed, as neglect of these sometimes causes improper curing. *First:* The steam curing chamber should be so tight as to prevent circulation of air and the consequent existence of a heated atmosphere not thoroughly saturated with water vapor, which would result in evaporation of water from architectural stone, building block and brick. *Second:* Steam should not be allowed to enter the curing chamber under prssure in such a manner as to strike the green architectural stone, building block and brick. The effect of this is to heat them quickly and cause evaporation of water from the product, resulting in ultimate destruction.

11. *Natural Curing.*—When it is found impracticable to introduce water vapor into the curing chamber, architectural stone, building block and brick should be handled in the same manner as previously described for steam curing on Paragraph 10, until they have become sufficiently hard so that the application of water does not injure the surface. Architectural stone, building block and brick should then be kept constantly wet on the surface by sprinkling with water for not less than seven (7) days for case (*a*) and fourteen (14) days for case (*b*), and the temperature should be maintained at not less than seventy (70) degrees Fahrenheit in the curing chamber. After removal from the curing chamber, architectural stone, building block and brick should be treated as already described for steam curing in Paragraph 10; that is, the period of storage in the yard should not less than fourteen (14) days.

REINFORCEMENT.

12. Architectural stone and flat building units subjected to cross bending shall be reinforced by means of rods placed about $1\frac{1}{2}$ in. from the tension surface, and the total sectional area for the reinforcement shall be not less than eight-tenths (0.8) of one (1) per cent of the cross sectional area of the concrete in the member reinforced. When any dimension exceeds eight (8) times the least dimension of any member, such member shall be reinforced to insure safety in handling.

FINISHING, MARKING AND HANDLING.

13. *Finishing.*—Architectural stone, building block and brick may have exposed surfaces treated by any of the various methods proposed by the INSTITUTE in the recommendations for treatment of concrete surfaces. All surfaces and arrises should be true and without imperfection.

14. *Marking.*—Full standard size should be marked for the purpose of identification, showing name of manufacturer or brand, date (month and year) made.

15. *Handling.*—Architectural stone, building block and brick should be handled with utmost care. When transported and subjected to rough handling they should be crated and packed in non-staining material in such a way as to insure no damage from chipping or abrasion. All large and heavy units should be provided with hooks for lifting. When necessary, the units should be provided with metal bonds for the purpose of tying to the masonry backing.

TESTS.

16. Architectural stone, building block and brick not usually being subjected to tensile stresses, their testing is ordinarily limited to compression and absorption.

Properly made architectural stone, building block and brick should—at an age of 28 days—sustain within failure a load of 1000 lb. per sq. in. of gross area as placed in the wall, making no allowance for hollow space.

After being dried to constant weight at a temperature of 212 degrees Fahrenheit, architectural stone, building block and brick 28 days old should not show more than five (5) per cent absorption after immersion in water for forty-eight (48) hours.

AMERICAN CONCRETE INSTITUTE

Founded 1905 and Incorporated 1906, as
NATIONAL ASSOCIATION OF CEMENT USERS
Charter Amended July 2, 1913.

PHILADELPHIA, PA.

PROPOSED REVISED RECOMMENDED PRACTICE FOR PLAIN CONCRETE PIPE AND DRAIN TILE.

This recommended practice is intended to cover general requirements for the manufacture of plain concrete pipe and drain tile.

MATERIALS.

1. The *cement* shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society. (Standard No. 1.)

2. (*a*) *Fine Aggregate.*—Fine aggregate shall consist of sand or screenings from hard, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear in.; not more than twenty-five (25) per cent shall pass a sieve having fifty (50) meshes per linear in. and not more than five (5) per cent shall pass a sieve having one hundred (100) meshes per linear in. Fine aggregate should not contain vegetable matter nor more than three (3) per cent of clay or loam. In no case should fine aggregate containing frost or lumps of frozen material be used.

Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement, and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength at least equal to the strength of briquettes composed of one (1)

part of the same cement and three (3) parts standard Ottawa sand by weight. The percentage of water used in making the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement, of the American Society of Civil Engineers. (See Standard No. 1.)

(*b*) *Coarse Aggregate.*—Coarse aggregate should consist of clean, hard, durable crushed rock or gravel graded in size, free from vegetable matter, and should contain no soft, flat or elongated particles. In no case should coarse aggregate containing frost or lumps of frozen material be used. The maximum size of the coarse aggregate shall be one-half ($\frac{1}{2}$) the thickness of the minimum wall section. Material should range from this size down, not more than five (5) per cent passing a screen having for (4) meshes per linear in.

(*c*) *Natural Mixed Aggregate*, such as bank-run gravel or artificially prepared mixtures of fine and coarse aggregate such as crusher-run stone, should not be used but should be screened over a one-quarter ($\frac{1}{4}$) in. screen and remixed to agree with the proportions as specified.

3. *Water* should be clean, free from oil, acids, strong alkalis or vegetable matter. An automatic measuring device should be used to measure the amount of water used in each batch of concrete, and after the desired consistency has been determined, this amount should be used in each batch until working conditions demand a change.

4. *Manufacture.*—In making pipe or drain tile by ordinary processes, using machines equipped with a revolving packer head, or with tampers and revolving core to form the shell, it will be found practicable to use aggregate having a maximum size of particles of one-quarter ($\frac{1}{4}$) in. for all sizes of pipe or tile up to twelve (12) in. In twelve (12) in. and larger sizes it will be found practicable to use aggregate having a maximum size of one-half ($\frac{1}{2}$) in. Deficiency in fine material in the aggregate causes difficulty in the manufacturing process; loss of pipe or tile when removed from the casing; rough surfaces, stone pockets and holes through which water spurts when internal water pressure tests

are applied. Deficiency in fine material within rather wide limits does not decrease the strength of the finished product. Excess of fine material causes low strength in finished pipe or tile and with ordinary mixtures tends to produce pipe or tile which will show seepage under internal pressure tests. The tendency to use an excess of fine material in the aggregate is to guarded against, because unless pipe or tile is tested the manufacturer may be deceived as to the quality of the product he is making, owing to the smooth and apparently workmanlike appearance of pipe or tile in which aggregate containing an excess of fine material has been used.

PROPORTIONS.

5. *Drain Tile.*—For drain tile up to and including ten (10) in. in diameter, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than three (3) cubic ft. of fine aggregate. For the manufacture of drain tile over ten (10) in. in diameter, in which coarse aggregate having the maximum size of particles of one-half ($\frac{1}{2}$) in. or more is used, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than five (5) cu. ft. of fine and coarse aggregate measured separately, and in no case should the mixture contain more than three (3) cu. ft. of fine aggregate to each bag of cement.

Pipe.—For the manufacture of pipe up to and including ten (10) in. in diameter concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two and one-half ($2\frac{1}{2}$) cu. ft. of fine aggregate. For the manufacture of pipe above ten (10) in. in diameter concrete shall be mixed in proportions of one (1) bag of Portland cement to not more than four (4) cu. ft. of fine and coarse aggregate measured separately. In no case should the mixture contain more than two and one-half ($2\frac{1}{2}$) cu. ft. of fine aggregate to each bag of cement.

A bag of Portland cement, 94 lb. net, shall be considered one (1) cu. ft. The method of measuring the materials for the concrete should be one which will insure separate and uniform proportions of each of the materials at all times. When cement in bulk is used the cement should be accurately measured in such manner as will insure that the measured amount of cement used as the equivalent of one (1) bag shall be ninety-four (94) lb.

MIXING.

6. *Mixing.*—The materials should be mixed to the desired consistency in a batch mixer of approved type, and the mixing should continue for at least one minute after all materials, including water, are in the mixer.

Retempering of mortar or concrete which has partially hardened, that is, remixing with additional materials or with water, shall not be permitted.

7. *Consistency.*—Concrete should be mixed as wet as can be used and allow the immediate removal of the outer casings from the pipe or drain tile. As an indication of the required consistency the pipe or tile should show on the outer surface web-like markings or water marks indicating free moisture after the removal of the jackets. Interior surfaces of the pipe or drain tile should show trowel marks caused by free water coming to the surface under the troweling action of the revolving packer head or core in case such is used.

FORMING.

8. Pipe or drain tile should be made in such a manner as to insure a dense and uniformly compacted product with smooth ends and inner surfaces. Pipe and drain tile should be formed so as to prevent laminations or planes of weakness. Each pipe or drain tile should be of a cylindrical section, the size being designated by the interior diameter. The thickness of the pipe or drain tile should be practically uniform throughout and should not be less than one-twelfth ($\frac{1}{12}$) the diameter with a minimum of one-half ($\frac{1}{2}$) in. for drain tile and three-quarter ($\frac{3}{4}$) in. for pipe. The diameter should not vary more than three (3) per cent from those specified.

WINTER WORK.

9. No pipe or drain tile should be made when the temperature of the atmosphere surrounding the machine is lower than fifty (50) degrees Fahrenheit. Aggregates and water should be heated when the temperature of either is lower than fifty (50) degrees Fahrenheit.

CURING.

10. Immediately after removing the outer casings from the pipe or drain tile they should be placed in a curing chamber where the temperature is not lower than fifty (50) degrees Fahrenheit and protected from drafts of air and from all exposure which will tend to cause evaporation of moisture from the concrete. Within twelve (12) hours after removing the pipe or drain tile from the machine the temperature in the curing chamber should be raised to between one hundred (100) and one hundred thirty (130) degrees Fahrenheit, and an atmosphere saturated with water vapor should be maintained by introducing water vapor from a boiler into the curing chamber. This water vapor should be introduced through a perforated pipe laid perforations down in a trough of water in the floor of the curing chamber.

(*a*) When the outside temperature during the daytime does not fall below 50 degrees Fahrenheit, the pipe or drain tile should be steam cured as described above for not less than forty-eight (48) hours, after which they may be removed from curing chamber and piled in the yard. They should then be sprinkled not less than three (3) times daily for seven (7) days. They may be shipped after having laid in the yard not less than fourteen (14) days.

(*b*) When the temperature of the outside atmosphere falls below 50 degrees Fahrenheit during the daytime, the pipe or drain tile should be steam cured for not less than ninety-six (96) hours, after which they may be piled in the yard. They need not receive any further treatment, but should remain in the yard for not less than fourteen (14) days.

In the steam curing process two requirements should be observed, as neglect of these sometimes causes improper curing. *First:* The steam curing chamber should be so tight as to prevent circulation of air and the consequent existence of a heated atmosphere not thoroughly saturated with water vapor, which would result in evaporation of water from the pipe walls. *Second:* Steam should not be allowed to enter the curing chamber under pressure in such a manner as to strike the green pipe or drain tile. The effect of this is to heat them quickly and cause the evaporation of water from the pipe or the tile walls.

11. When it is found impracticable to introduce water vapor into the curing chamber, the pipe or drain tile should be handled in the same manner as previously described for steam curing in Paragraph 10, until they have become sufficiently hard so that the application of water does not injure them. The pipe or drain tile should then be kept constantly wet on the surface by sprinkling with water for not less than seven (7) days for case (*a*) and fourteen (14) days for case (*b*), and the temperature should be maintained at not less than seventy (70) degrees Fahrenheit in the curing chamber. After removal from the curing chamber the pipe or tile should be treated as already described for steam curing in Paragraph 11, except that the period of storage in the yard should be not less than fourteen (14) days.

12. In cases where it is desired to use a combination of steam and water curing, the pipe or drain tile should be cured in the steam chamber under conditions described above for steam curing in Paragraph 10, until such time as they are sufficiently hardened to permit piling one on top of another. They may then be removed to a sprinkling chamber where they will be at all times protected from drafts of air. Here they should be kept constantly wet on the surface by sprinkling for a period of not less than two (2) days for case (*a*) and not less than seven (7) days for case (*b*). The temperature in the sprinkling chamber should be maintained at not less than seventy (70) degrees Fahrenheit for the periods mentioned. After removal from the sprinkling chamber the pipe or tile should be treated in the manner described above for steam curing in paragraph 11, except that the period of storage in the yard shall be not less than twenty-one (21) days.

TESTS.

13. Indications of good quality in pipe and drain tile are:

First: High Supporting Strength.

Second: Low Percentage of Absorption.

In making strength tests of drain tile or pipe, the methods proposed by Committee C-6 of the American Society for Testing Materials should be followed, and the specimens should have minimum average ordinary supporting strength in accordance with the following table:

Diameter, inches.	Pounds per Linear Foot.
8	1000
10	1050
12	1150
14	1200
16	1500
18	1700
20	2100
22	2300
24	2500

Pipe or drain tile which show a small percentage of absorption are to be preferred in every respect to those that show high absorption. In making examination to determine the absorption, it is necessary to dry pipe or tile at a temperature of 212 degrees Fahrenheit, until they show no further loss in weight. Pipe or tile will absorb their full capacity of water within forty-eight (48) hours after immersion. Tests have shown that high strength and low absorption go hand in hand.

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PHILADELPHIA, PA.

PROPOSED RECOMMENDED PRACTICE FOR CONCRETE FENCE POSTS

This recommended practice is intended to cover general requirements for the manufacture of concrete fence posts.

Materials.

1. The *cement* shall meet the requirements of the Standard Specifications for Portland Cement, adopted by the American Society for Testing Materials, August 16, 1909, with all subsequent amendments and additions thereto adopted by said Society. (Standard No. 1.)

2. (*a*) *Fine Aggregate.*—Fine aggregate should consist of sand or screenings from hard, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent should pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent should pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate should not contain vegetable matter nor more than three (3) per cent of clay or loam. In no case should fine aggregate containing frost or lumps of frozen material be used.

Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement, and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a

tensile strength at least equal to the strength of briquettes composed of one (1) part of the same cement and three (3) parts standard Ottawa sand by weight. The percentage of water used in making the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of Standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement, of the American Society of Civil Engineers.

(*b*) *Coarse Aggregate.*—Coarse aggregate should consist of clean, hard, durable crushed rock or gravel graded in size, free from vegetable matter, and should contain no soft, flat or elongated particles. In no case should coarse aggregate containing frost or lumps of frozen material be used. Coarse aggregate for concrete fence posts should vary in size from one-quarter ($\frac{1}{4}$) in. to one-half ($\frac{1}{2}$) in.

(*c*) *Natural Mixed Aggregate*, such as bank-run gravel or artificially prepared mixtures of fine and coarse aggregate such as crusher-run stone, should not be used but should be screened over a one-quarter ($\frac{1}{4}$) in. screen and remixed to agree with the proportions as specified.

3. *Water* should be clean, free from oil, acids, strong alkalis or vegetable matter. An automatic measuring device should be used to measure the amount of water used in each batch of concrete, and after the desired consistency has been determined, this amount should be used in each batch until working conditions demand a change.

PROPORTIONS.

4. For concrete fence posts containing no coarse aggregate, the concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two and one-half ($2\frac{1}{2}$) cubic ft. of fine aggregate. For concrete fence posts in which coarse aggregate is used, concrete should be mixed in proportions of one (1) bag of Portland cement to not more than two (2) cubic ft. of fine aggregate and three (3) cubic ft. of coarse aggregate.

A bag of Portland cement, ninety-four (94) pounds net, shall be considered one (1) cubic ft. The method of measuring the materials for the concrete shall be one which will insure separate

and uniform proportions of each of the materials at all times. When cement in bulk is used the cement shall be accurately measured in such manner as will insure that the measured amount of cement used as the equivalent of one (1) bag shall be ninety-four (94) pounds.

MIXING.

5. *Mixing.*—The materials should be mixed to the desired consistency in a batch mixer of approved type, and the mixing should continue for at least one minute after all materials, including water, are in the mixer.

6. *Retempering* of mortar or concrete which has partially hardened, that is, remixing with additional materials or with water, should not be permitted.

7. *Consistency.*—For concrete fence posts, concrete should be mixed wet enough that no tamping will be required, compactness in filling the molds being secured by agitating the concrete either by stirring it or by jarring the mold.

WINTER WORK.

8. No concrete fence posts should be made when the temperature of the atmosphere surrounding the mold is lower than fifty (50) degrees Fahrenheit. Aggregates and water should be heated when the temperature of either is lower than fifty (50) degrees Fahrenheit.

CURING.

9. *Steam Curing.*—Immediately after completing the manufacture of concrete fence posts, they should be placed in a curing chamber where the temperature is not lower than fifty (50) degrees Fahrenheit, and protected from drafts of air and from all exposure which will tend to cause evaporation of moisture from the concrete. Within twelve (12) hours after removing concrete fence posts from the place of manufacture, the temperature in the curing chamber should be raised to between one hundred (100) and hundred and thirty (130) degrees Fahrenheit, and an atmosphere saturated with water vapor maintained by introducing water vapor from a boiler into the curing chamber. This water vapor should be introduced through a perforated pipe laid per-

forations down in a trough of water in the floor of the curing chamber.

(*a*) When the outside temperature during the day time does not fall below fifty (50) degrees Fahrenheit, concrete fence posts shall be steam cured, as described above, for not less that forty-eight (48) hours, after which they may be removed from the curing chamber and piled in the yard. They shall then be sprinkled not less than three (3) times daily for seven (7) days. They may be used after having laid in the yard not less than thirty (30) days.

(*b*) When the temperature of the outside atmosphere falls below fifty (50) degrees Fahrenheit during the daytime, concrete fence posts shall be steam cured for not less than ninety-six (96) hours, after which they may be piled in the yard. They need not receive any further treatment, but shall remain in the yard for not less than thirty (30) days.

In the steam curing process, two requirements should be observed, as neglect of these sometimes causes improper curing. *First:* The steam curing chamber should be so tight as to prevent circulation of air and the consequent existence of a heated atmosphere not thoroughly saturated with water vapor, which would result in evaporation of water from concrete fence posts. *Second:* Steam should not be allowed to enter the curing chamber under pressure in such a manner as to strike the green concrete fence posts. The effect of this is to heat them quickly and cause evaporation of water from the product, resulting in ultimate destruction.

10. *Natural Curing.*—When it is found impracticable to introduce water vapor into the curing chamber, concrete fence posts should be handled in the same manner as previously described for steam curing in Paragraph 9, until they have become sufficiently hard so that the application of water does not injure the surface. Concrete fence posts should then be kept constantly wet on the surface by sprinkling with water for not less than seven (7) days for case (*a*) and fourteen (14) days for case (*b*), and the temperature should be maintained at not less than seventy (70) degrees Fahrenheit in the curing chamber. After removal from the curing chamber, concrete fence posts should be treated as already described for steam curing in Paragraph 9; that is, the period of storage in the yard should be not less than thirty (30) days.

REINFORCEMENT.

11. *Concrete fence posts* and *braces* should be reinforced by means of rods spaced symmetrically and placed not less than one-half ($\frac{1}{2}$) in. nor more than three-quarters ($\frac{3}{4}$) in. from the surface of the post, and the total sectional area of the reinforcement should not be less than one and two-tenths (1.2) per cent of the cross-sectional area of the post measured at the ground line. In case the post is of square cross-section, the reinforcement should consist of four (4) members placed in the corners of the post. Reinforcing members which provide what is known as mechanical bond between concrete and reinforcing are to be preferred.

12. *Concrete line posts*, which usually average about four (4) in. by four (4) in. in section measured at the ground line, should be reinforced with not less than four (4) one-quarter ($\frac{1}{4}$) in. steel round rods or other reinforcement of equal cross section.

13. *Concrete corner posts*, which vary more in size of sectional dimensions taken at the ground line, should be reinforced with not less than four (4) steel rods or other reinforcement of equal cross-section, as follows:

6 by 6-in. post, $4\frac{3}{8}$-in. round rods.
8 by 8-in. post, $4\frac{1}{2}$-in. round rods.
12 by 12-in. post, $4\frac{3}{4}$-in. round rods.

FASTENING LINE WIRES.

14. A method of fastening line wires to concrete fence posts should be adopted which is simple, economical and easily renewed at any time, and which will not reduce the strength of the post. A common and satisfactory method of fastening a wire fence to concrete posts is by means of a wire tie, known as the Western Union Twist. One end of the tie is twisted around the line wire, the other end being brought around the post and attached to the line wire.

HANDLING.

15. Concrete fence posts should be handled with utmost care. When transported and subjected to rough handling, they should be packed in straw, or shavings, or similar material in such a way as to insure against damaging.

L. C. Wason
Ch.

REPORT OF COMMITTEE ON TREATMENT OF CONCRETE SURFACES.

The Committee begs to submit the following:

1. Proposed Standard Specifications for Portland Cement Stucco on Wood Lath (see page 83).

2. In order to secure dustless sidewalks and floors amend the Standard Specifications by inserting, as noted below, the following:

Fine aggregate shall consist of a crushed stone which tests or experience have proved to withstand abrasion well. The stone in any locality that is most satisfactory for macadam roads is suitable. It shall be graded from fine to coarse, the larger particles predominating in quantity, and passing, when dry, a screen having one-half (½) inch round holes, and preferably none shall pass a screen having thirty (30) meshes per linear inch.

Standard No. 2. Standard Specifications for Portland cement Sidewalks. Insert in place of paragraph 2 (*a*); retain second paragraph of 2 (*a*).

Standard No. 13. Standard Specifications for Plain Concrete Floors. Insert in place of paragraph 2 (*b*).

Standard No. 14. Standard Specifications for Reinforced Concrete Floors. Insert in place paragraph 2 (*b*).

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PROPOSED STANDARD SPECIFICATIONS FOR PORTLAND CEMENT STUCCO ON WOOD LATH.

Paragraph marked (*a*) applies only to single layer work.
Paragraph marked (*b*) applies only to double layer work.

Materials.

1. *Cement.*—The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials, and adopted by this Institute (Standard No. 1).

2. *Fine Aggregate* shall consist of sand, crushed stone, or gravel screenings, graded from fine to coarse, passing when dry a screen having $\frac{1}{8}$ in. diameter holes, shall be preferably of silicious materials, clean, coarse, free from loam, vegetable or other deleterious matter.

3. *Lime.*—The lime shall be thoroughly hydrated either by the manufacturer, or the contractor. If hydrated by the contractor, it shall be slaked in sufficient water to make a soft paste and allowed to stand at least one week before being applied to the wall.

4. *Hair or Fibre.*—There shall be used only first quality long hair, free from foreign matter, or a long fibre well combed out.

5. *Coloring Matter.*—Only inorganic colors shall be used, which are not affected by lime, Portland cement, other ingredients of the mortar or the weather.

6. *Water* shall be clean, free from oil, acid, strong alkalies or vegetable matter.

PREPARATION OF MORTAR.

7. *Mixing.*—The ingredients of the mortar shall be thoroughly mixed to a uniform color, sufficient water added to obtain the desired consistency, and the mixing shall continue until the cement and lime are uniformly distributed and the mass is uniform in color and homogeneous.

The hair or fibre shall be added during the process of wet mixing.

8. *Measuring Proportions.*—Methods of measurement of the proportions of the various ingredients, including the water, shall be used which will secure separate uniform measurements at all times. All proportions stated are by volume. A bag (94 lb. net) of cement shall be assumed to contain 1 cu. ft. Lime when used shall be measured in the form of putty. Hydrated lime shall be made into putty before being measured.

9. *Quantity.*—There shall not be mixed at one time more mortar than will be used within one hour. Mortar which has begun to stiffen or take on its inltial set shall not be used.

10. *Hand Mixing.*—The mixing shall be done on a water-tight platform and the materials shall be turned until they are homogeneous in appearance and color.

11. *Consistency.*—The materials shall be mixed so as to provide sufficient water to insure a proper bonding and a dense mortar free from voids.

12. *Retempering.*—Retempering mortar, *i. e.*, remixing with water after it has partially set, shall not be allowed.

STRUCTURE.

13. *Framing.*—Studs spaced at not more than 16 in. on centers shall be run from foundation to rafters without any intervening horizontal grain of the wood. These studs shall be tied together just below the floor joists by 6-in. boards which will be let into the studs on their inner side, so as to be flush and securely nailed to them. These boards will also act as sills for the floor joists, which in addition will be securely spiked to the side of the studs.

14. *Sheathing.*—Sheathing boards shall be not less than 6 in. or more than 8 in. wide, dressed on one or both sides to a uniform

thickness of $\frac{7}{8}$ in. They shall be laid diagonally across the wall studs and fastened with two nails at each stud.

15. *Insulation.*—When quilting, felt, or other insulating material is to be used it shall be applied to the sheathing boards under the inside waterproofing.

16. *Inside Waterproofing.*—Over the sheathing boards shall be laid in horizontal layers, beginning at the bottom, a substantial paper well impregnated and thoroughly waterproofed with tar or asphalt. The bottom strip shall lap over the base board at the bottom of the wall, and each strip shall lap the one below at least 2 in. The paper shall lap the flashings at all openings. When required, the lower horizontal edge of each strip shall be cemented with hot or liquid tar or asphalt compound, to the strip below and to the grounds of flashings at all openings. All tacking shall be within 2 in. of the top horizontal edge, where tacks will be covered by the lap of the strip above.

17. *Furring.*—Furring $\frac{7}{8}$ in. thick by 2 in. wide shall be laid vertically 12 in. on centers over sheathing paper and nailed every 8 in. with 5*d* nails.

18. *Preparation of Original Surface.*—All roof gutters shall be fixed and down-spout hangers and all other fixed supports and fasteners shall be put up before the plastering is done, so there will be no break made in the plastering where they are permanently fixed.

Wall copings, balustrade rails, chimney caps, cornices, etc., shall be built of concrete, stone, tile or metal with ample overhang drip grooves or lip, and water tight joints, to keep water from behind the plaster.

If wood sills are used, they should project well from the face of the plaster and have ample drip groove or lip.

Lath shall be stopped far enough above the level of the ground to be free from ground moisture.

Care should be taken to provide for placing all trim the proper distance from the studding or furring to show its right projection after the plaster is on.

19. *Lath.*—The lath shall be standard quality, narrow plastering lath 4 ft. long and not less than $\frac{3}{8}$ in. thick.

20. *Application of Lath.*—(*a*) Single layer work. Lath shall be placed horizontally on the furring with $\frac{1}{2}$ in. openings between

them. Joints shall be broken every twelfth lath. They shall be nailed at each furring with 4 *d* galvanized nails.

(*b*) Double layer work. The lath shall be applied in two layers. Both layers shall be placed diagonally to the furring in opposite directions, the angle being such that the 4 ft. lath will span three spaces between furring. The space between lath for key shall be 1 in. in each layer. Joints shall be broken every twelfth lath in each layer. The first layer shall be applied directly to the furring and nailed with 4*d* galvanized nail at every point of contact. A second layer of lath shall be applied over the first with joints broken; *i. e.*, ends of lath of the second layer shall not come over the same furring as those of the first layer. The second layer shall be nailed to each furring with 4*d* galvanized nails.

21. *Corners and Openings.*—Around all openings and bent-over corners place a 6-in. strip of galvanized metal lath firmly stapled over wood lath with $1\frac{1}{4}$-in. x 14 gage galvanized staples.

22. *Spraying.*—Wet lath thoroughly on both sides and allow water to be absorbed before applying the first coat of plaster.

MORTAR COATS.

23. *Plaster.*—The *first coat* shall contain not more than two and one-half ($2\frac{1}{2}$) parts of sand to one (1) part of Portland cement by volume. If lime putty is added, it shall not be in excess of one-third ($\frac{1}{3}$) of the volume of cement. Hair or fibre may be added in sufficient quantity to bond the mortar.

For *second coat*, the proportion of sand to cement shall not be greater than $2\frac{1}{2}$ to 1 by volume, nor shall more than $\frac{1}{3}$ part of lime putty be added.

For *third coat*, the proportion of sand to cement shall not be less than 2 to 1 nor more than $2\frac{1}{2}$ to 1, by volume, nor shall more than $\frac{1}{3}$ part of lime putty be added.

24. *Application.*—The plastering should be carried on continuously in one general direction, without allowing the plaster to dry at the edge. If it is impossible to work the full width of the wall at one time, the joint should be at some natural division of the surface, such as a window or door.

The first coat shall be applied to the outside of the lath and pushed through sufficiently to give a good key. If subse-

quent coats are applied they shall be well troweled to insure good bond with the previous coat.

25. *Roughing.*—Soon after applying and before the initial set has taken place, the surface of the coats which are to receive succeeding coats shall be roughened with a saw-toothed paddle or other suitable device.

26. *Dampening.*—Before applying mortar the surface of the preceding coat shall be thoroughly wetted to prevent absorption of water from the fresh mortar.

27. *Thickness of Coat.*—The first coat shall have a minimum thickness over the lath at any point of not less than $\frac{1}{4}$ in. The intermediate coat shall have a thickness of not less than $\frac{1}{4}$ in. or more than $\frac{3}{8}$ in. The final coat shall have a thickness of $\frac{1}{4}$ in. when placed over an intermediate coat, or of $\frac{3}{8}$ in. when placed directly on the scratch coat.

28. *Drying Out.*—The final coat shall not be permitted to dry out rapidly and adequate precaution shall be taken, either by sprinkling frequently after the mortar has set hard enough to permit it or by hanging wet burlap or other material over the surface.

29. *Freezing.*—Stucco should never be applied when the temperature is below freezing.

FINISH.

30. *Smooth Troweled.*—The finishing coat shall be troweled smooth with a metal trowel with as little rubbing as possible.

31. *Stippled.*—The finishing coat shall be troweled smooth with a metal trowel with as little rubbing as possible, and then shall be lightly patted with a brush of broom straw to give an even, stippled surface.

32. *Sand Floated.*—The finishing coat, after being brought to a smooth, even surface, shall be rubbed with a circular motion of a wood float with the addition of a little sand to slightly roughen the surface. This floating shall be done when the mortar has partially set.

33. *Sand Sprayed.*—After the finishing coat has been brought to an even surface, it shall be sprayed by means of a wide, long fibre brush—a whisk-broom does very well—dipped into a creamy mixture of equal parts of cement and sand, mixed fresh every

30 minutes and kept well stirred in the bucket by means of the whisk-broom or a paddle. This coating shall be thrown forcibly against the surface to be finished. This treatment shall be applied while the finishing coat is still moist and before it has attained its final set, *i. e.*, within 3 to 5 hours. To obtain lighter shades add hydrated lime of 5 to 15 per cent. of the volume of the cement.

34. *Splatter Dash or Rough Cast.*—After the finishing coat has been brought to a smooth, even surface and before attaining final set, it shall be uniformly coated with a mixture of one part cement and two parts of sand thrown forcibly against it to produce a rough surface of uniform texture when viewed from a distance of 20 ft. Special care shall be taken to prevent the rapid drying out of this finish.

35. *Pebble Dash.*—After the finishing coat has been brought to a smooth, even surface, and before attaining initial set, clean round pebbles or other material as selected, not smaller than $\frac{1}{4}$ in. or larger than $\frac{3}{4}$ in., previously wetted, shall be thrown forcibly against the mortar so as to embed themselves in the fresh mortar. They shall be distributed uniformly over the surface of the final coat and may be pushed back into the mortar with a clean wood trowel, but no rubbing of the surface shall be done after the pebbles are embedded.

36. *Exposed Aggregates.*—The finishing coat shall be composed of an approved, selected coarse sand, marble dust, granite dust or other special material, in the proportion given for finishing coats and within 24 hours after being applied and troweled to an even surface, shall be scrubbed with a stiff brush and water. In case the cement is too hard a solution of one part hydrochloric acid in four parts of water by volume can be used in place of water. After the aggregate particles have been uniformly exposed by scrubbing, particular care shall be taken to remove all traces of the acid by thorough spraying with a hose.

37. *Mortar Colors.*—When it is required that any of the above finishes shall be made with colored mortar, not more than 6 per cent. of the weight of Portland cement shall be added to the mortar in the form of finely ground coloring matter.

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SOME FURTHER RESULTS OBTAINED IN INVESTIGATING THE PROPERTIES OF PORTLAND CEMENTS HAVING A HIGH MgO CONTENT.

By P. H. Bates.*

This paper contains further data concerning high Magnesium Portland cements, obtained from cements burned in the experimental plant of this Bureau. It contains the results obtained from a second series of burns, as well as later tests of the physical specimen of the first series reported at the last meeting of this Institute. The same procedure was followed in the present series as in the first, but in the present investigation the composition was changed so that the resulting cements have a lower lime-magnesia content and a higher silica and higher alumina-iron oxide content. These two series of burns, having produced cements of both normal composition, containing less than 2 per cent magnesia, and abnormal composition, containing over 25 per cent magnesia, should, with the complete studies of their chemical, petrographic and physical properties, extending over long periods, give a clear idea of the effect of magnesia in Portland cement when it replaces lime. However, in this paper the results of the strength tests of the second series do not extend beyond six months, and the strength of the cements of the first series beyond twelve months, in the case of the neat and sand specimens, and beyond eighteen months in the case of the concrete specimens.

The Burning of the Cements.

The raw materials used in this second series were clay, limestone, dolomite and kaolin—the same materials as used in the first series excepting the use of kaolin instead of feldspar, this being necessitated by the higher alumina content. However, in either case the amount of feldspar or kaolin used was relatively small. As in the first series, the low magnesia cement was burned from a mix containing no dolomite; with increasing magnesia

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content, the raw mix contained increasing amounts of dolomite until in Burn 33 all dolomite and no limestone was used. After grinding in a ball mill until 85 per cent passed a 200-mesh sieve, the raw mix was burned in a 2 x 20 ft. gas-fired rotary kiln. The resulting clinker, without storage, was ground in ball mills, with the addition of sufficient plaster to produce a SO_3 content of about 1.6 per cent.

The average temperature of each burn, readings having been taken every 15 minutes with a Wanner pyrometer, was as follows:

Burn No.	Temperature deg. C.	Burn No.	Temperature deg. C.
33	1413	38	1434
34	1410	39	1450
35	1420	40	1447
36	1437	41	1446
37	1423	..	....

These temperatures are lower than those required for the cements of the first series, as would be expected from the higher alumina-iron oxide content. In general the phenomena encountered in burning were similar in both series. The Burn producing cement of about 14 per cent magnesia content acted quite differently in the kiln and the clinker behaved differently on cooling than those containing 10 per cent and less magnesia. In the kiln there was but a slight range of temperature in which either a decidedly underburned or decidedly overburned clinker was produced. Furthermore, the clinker of the higher magnesia content started to dust immediately (though not to a very marked extent until at the end of 24 hours) Fig. 4, and finally at the end of 4 months was turned to a powder which almost entirely passed a 200-mesh sieve, though there still remained a few lumps about $\frac{1}{8}$-in. in diameter. It is to be noted that this dusting occurred in air-tight containers and was not a slaking but a reversion of the β or β' orthosilicate of lime to the γ form which occupied about 10 per cent more volume than either of the former ones.

The clinker of the high magnesia cements—those over 10 per cent—was very hard and glassy, of a peculiar reddish yellow appearance; which when ground produced cement of a decided yellowish tinge, the concrete made therefrom having a decided "muddy color."

PETROGRAPHIC ANALYSES.

The constituents present were the same as those noted in the previous burns—tricalcium silicate ($3CaO \cdot SiO_2$), tricalcium aluminate ($3CaO \cdot Al_2O_3$,) orthosilicate of lime—β', β and γ forms ($2CaO \cdot SiO_2$), monticellite ($MgO \cdot CaO \cdot SiO_2$), spinel (MgO .

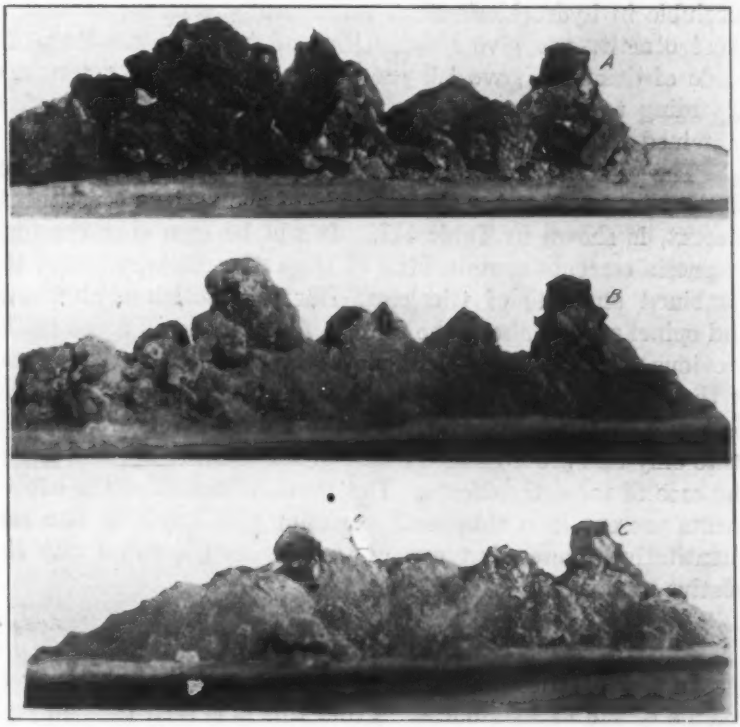

FIG. 4.—PROGRESSIVE DUSTING OF THE CLINKER OF BURN 33 (MADE FROM A RAW MIX CONTAINING DOLOMITE AND CLAY). A—HOT CLINKER; B—30 MINUTES AFTER DROPPING FROM KILN; C—24 HOURS AFTER DROPPING FROM KILN.

Al_2O_3), and finally a very little free magnesia in the two burns containing the highest magnesia content. However, in this series monticellite was noted in the burn containing 8.03 per cent magnesia, whereas in the first series it was not noted below the burn containing 9.5 per cent. The β' orthosilicate was a rather

prominent constituent compared with the first series when its presence was noticed only after considerable search. In passing it might be observed that in other cement investigations at this laboratory β' orthosilicate has been noted to have a tendency to form in the higher alumina cements.

It will be recalled that the monticellite and spinel are rather insoluble in hydrochloric acid, consequently cements containing these constituents give a large "insoluble" residue. Burn 33, made of dolomite, gave 5.9 per cent "insoluble" as determined according to Bureau of Standards' Circular No. 33, and when examined petrographically was found to be very largely spinel.

The "approximate quantitative" petrographic analyses of the clinkers, showing the amounts of the various constituents present, is shown in Table III. It will be seen that the high magnesia cements contain little of the orthosilicate, whereas the combined amounts of tricalcium silicate, tricalcium aluminate and spinel remain about the same. Apparently, as noted in the previous paper, the monticellite has been produced at the expense of the orthosilicate and not of the tricalcium silicate. It should be borne in mind, however, that the figures given are approximate only and are high in the case of the monticellite and low in the case of the orthosilicate. But an examination of the constituents present in a thin section cannot give anything like real quantitative figures, but can only show in a general way the relative amounts.

TIME OF SET AND CONSTANCY OF VOLUME.

In Table II is shown the time of set and the constancy of volume of the various burns. From this it is seen that all pass the four constancy of volume tests with the exception of the highest magnesia cement; had the pats of this burn been allowed to obtain a final set before subjecting them to the boiling and steaming tests, it is possible that their condition after the test would have been somewhat better.

So far as the time of set is concerned, it will be seen that there is no marked difference in any of the cements until the one containing 10.33 per cent magnesia is reached, when there is a marked quickening of the set; the next two higher magnesia burns developed an almost "flash" initial set, marked by the evolution

TABLE I.—CHEMICAL ANALYSES OF THE VARIOUS CEMENTS.

Burn No.	33.	34.	35.	36.	37.	38.	39.	40.	41.
SiO_2	22.35	22.33	22.11	21.76	21.53	21.39	21.38	21.22	21.60
Al_2O_3	8.95	8.32	8.79	8.50	8.32	7.85	8.36	8.46	8.15
Fe_2O_3	3.39	3.24	3.10	3.16	3.19	3.43	3.15	3.27	3.35
CaO	36.32	43.92	49.30	53.77	56.30	57.26	58.02	61.40	62.67
MgO	25.53	19.45	13.96	10.33	8.03	7.80	6.62	3.59	2.01
SO_3	1.43	1.73	1.83	1.61	1.62	1.67	1.62	1.56	1.63
Na_2O	.38	.00	.09	.13	.06	.09	.03	.00	.06
K_2O	.56	.16	.17	.27	.23	.38	.15	.16	.08
Ig. loss	1.01	.71	.68	.47	.59	.55	.61	.67	.42
	99.92	99.86	100.03	100.00	99.87	100.42	99.94	100.33	99.97

TABLE II.—TIME OF SET, NORMAL CONSISTENCY, SPECIFIC GRAVITY AND CONSISTENCY OF VOLUME OF THE VARIOUS CEMENTS.

Burn No.	Normal Consistency.	Time of Set.				Specific Gravity.	Boil.	Steam.	Air, 28 days.	Water, 28 days.
		Gilmore.		Vicat.						
		Initial.	Final.	Initial.	Final.					
		H. M.	H. M.	H. M.	H. M.					
33	18.5	4:00	48:00	0:30	25:00	3.275	soft	soft	warped	OK
34	....	*:10	*1:30	*:05	*:15	3.225	OK	OK	OK	OK
35	24.5	*:08	*1:25	*:05	*:12	3.110	OK	OK	OK	OK
36	18.5	2:00	4:00	1:30	3:30	3.240	OK	OK	OK	OK
37	19.0	3:15	5:50	2:10	5:00	3.230	OK	OK	OK	OK
38	19.0	3:05	5:00	2:20	4:10	3.224	OK	OK	OK	OK
39	19.5	2:35	5:25	1:55	4:15	3.200	OK	OK	OK	OK
40	19.5	2:10	4:45	1:35	4:00	3.193	OK	OK	OK	OK
41	19.5	2:05	5:40	1:35	5:00	3.205	OK	OK	OK	OK

* All test pieces became quite warm—particularly the Vicat pieces.

TABLE III.—APPROXIMATE PETROGRAPHIC ANALYSES OF THE VARIOUS BURNS

Burn No.	* Tricalcium Silicate, Tricalcium Aluminate.	β Calcium Orthosilicate.	β' Calcium Orthosilicate.	"Ferrite."	Monticellite.	*Spinel.
33	52.0	9.8	3.7	11.3	23.2	Some
34	53.2	18.6	2.1	8.9	17.2	Some
35	46.8	25.2	1.7	11.4	14.9	Little
36	50.6	29.8	None	10.5	9.1	Very little
37	51.2	35.8	None	9.7	4.3	None
38	53.0	37.2	None	8.9	0.9	None
39	54.3	36.6	None	9.1	None	None
40	55.7	35.8	None	8.5	None	None
41	56.2	33.5	None	9.9	None	None

* Owing to the optical properties (all appearing isotropic in certain cases), Spinel, tricalcium aluminate and tricalcium silicate cannot be readily distinguished from one another in thin sections, and the actual amount of either of these cannot be determined; since, however, the alumina content was very nearly the same in every case and since with decreasing magnesia content, the amount of Spinel decreased, some idea may be formed of the relative amount of the tricalcium silicate.

of much heat, which had a tendency to dry out the specimens, producing a rather false final set. The burn containing 25.53 per cent magnesia gave a much slower initial set and a longer final set with the Gilmore specimens, while with the Vicat specimens the initial set was rather rapid, but the final set slow. The heat developed in this case, while marked, was very much less than in the case of the other two cements showing quick set, which slighter development would partially explain the difference in the results obtained with the two sets of specimens.

When the quick time of set of this high magnesia cement is studied in connection with the quantitative petrographic analysis, an explanation of this behavior is possibly obtained. In Table III the low amount of the orthosilicate is seen; this is the constituent of normal cement, which hydrates very slowly, producing the longer time increase in strength, and which also seems to act as a retarder on the other quick setting compounds—not so much in a chemical way, but in a mechanical, being fused around grains of these compounds and preventing the rapid action of water on them. Furthermore, it is seen from this table that the content of the quick setting (quick hydrating) compounds—the tricalcium silicate and aluminate—is about the same throughout the series. Consequently, this large excess of the quick setting material would produce the results obtained. That the monticellite does not act as such a good retarder as the orthosilicate, is shown in the microscopic appearance of the clinker—the latter in a normal clinker is well scattered throughout the mass, surrounding and enclosing grains and crystals of both the tricalcium silicate and aluminate, whereas the former appears invariably segregated in well defined masses or crystals. That Burn 33 should show a slower set than Burns 34 and 35 in possibly explained by the less tricalcium aluminate content, this having been reduced by the spinel which is present in greater quantities than in any of the other burns.

COEFFICIENT OF EXPANSION OF CONCRETE.

In Table VI is shown the results of the measurements made on 1 : $1\frac{1}{2}$: $4\frac{1}{2}$ gravel concrete bars, stored either in water or air, to determine their relative expansion on being aged. This table includes the results obtained from concrete made from cements

TABLE VI.—EXPANSION (IN PERCENTAGE OF ORIGINAL LENGTH) OF 1 : 1½ : 4½ CONCRETE BARS MADE FROM CEMENTS OF BOTH SERIES.—READINGS MADE AT END OF PERIOD STATED.

Burn No.	Stored in	1 week.	2 weeks.	1 month.	2 months.	3 months.	4 months.	6 months.	8 months.	11 months.	14 months.	18 months.
16	Air	.003	.014	.018	.024	.019	.032	.036	.044	.044	.040	.047
	Water	.007	.003	.019	.035	.063	.052	.053	.058	.062	.062	.062
25	Air	.007	.016	.024	.019	.007	....	.011	.016	.017	.017	.014
	Water	.003	.024	.07	.086	.129	.194	.193	.193	.195	.195	.203
26	Air	.018	.022	[illegible]	.036	.048	.053	.052	.051	.056	.056	.066
	Water	−.011	−.005	−[illegible]	....	−.003	−.004	−.008	−.007	−.029	−.018	−.013
27	Air	.017	.032	.036	.033	.038	.044	.055	.062	.069	.060	.069
	Water	.009	.012	.023	.026	.027	.035	.034	.037	.036	.042	.059
28	Air	.008	.017	.019	.018	.045	.042	.044	.050	.054	.051	.053
	Water	.003	.010	.021	.031	.033	.033	.034	.040	.046	.045	.047
29	Air	.016	.035	.044	.037	.047	.046	.047	.050	.051	.052	.084
	Water	−.001	+.008	+.008	+.020	+.007	+.008	+.028	+.020	+.027	+.025	+.021
30	Air	.082	.067	.061	.043	.029	.028	.027	.022	.022	.021	.026
	Water	−.003	+.008	+.002	+.005	+.010	+.008	+.016	+.016	+.023	+.023	+.034
31	Water	.021	.028	.052	.057	.073	.077	.072	.066	.067	....	....
36	Air	.048	.058	.059	.073	.082	.090	.085	.085	.091	....	....
	Water	−.009	.000	+.004	+.008	+.008	+.009	+.025	+.033	+.034	....	....
37	Air	.028	.032	.042	.049	.055	.057	.057	.058	....	....	....
	Water	−.022	−.024	−.015	−.009	−.004	+.007	+.012	+.022	....	....	....
38	Air	.015	.015	.014	.016	.022	.026	.023	.023	.074	....	....
	Water	.008	.024	.043	.050	.050	.044	.055	.061	.062	....	....
39	Air	.005	.031	.039	.048	.058	.062	.059	.059	.060	....	....
	Water	.001	.044	.044	.042	.043	.034	.063	.090	.090	....	....
40	Air	+.020	+.016	+.012	+.006	+.001	−.001	....	+.006	+.011	....	....
	Water	.044	.050	.055	.057	.055	.055	.061	.066	.077	....	....
41	Air	.052	.056	.056	.061	.068	.067	.062	.068	....	....	....
	Water	−.008	.000	+.003	+.005	+.003	+.004	....	....	....	....	....

NOTE.—With the exception of those indicated, all bars stored in *air* showed a negative expansion.
With the exception of those indicated, all bars stored in *water* showed a positive expansion.

from both series. Unfortunately, owing to the very slight strengths of the very high magnesia cements, bars of the size used could not be made from these. These bars were about 45 in. long by about 5 in. in cross section, having heavy copper wire gage marks very nearly one meter apart. They were molded in well-oiled wooden forms, the forms were allowed to remain for 24 hours, then all removed excepting the bottom on which the bars were allowed to remain for 1 week. The bars intended for storage in water were covered with wet burlap, which was wet every morning and evening; but during the night it dried out, so that the bars seemed dry and as a result the second readings, made at the end of a week, usually showed a contraction for those bars marked stored in water as well as those stored in air.

The readings were made with an extensometer made of two parallel $\frac{3}{4}$ by $\frac{3}{4}$-in. by 42-in. oak rods, joined at the ends and at two equivalent places between, with $\frac{3}{4}$ by $\frac{3}{4}$-in. by 3-in. oak cross rods. Through one of the end cross pieces there was securely fastened a steel set-screw and on the other an Ames dial, reading to .001 mm. In making the measurements, the set screw was brought up to the outer side of one of the copper gage points and then the spindle of the Ames dial brought against the outer side of the other gage point. The reading was then noted and could be checked to about .003. Immediately after making the reading the distance between the end of the spindle and the end of the set-screw was determined on a microscopic comparator, using the same meter bar in all cases. All readings are corrected to 20 deg. C., using .000005 and .000006 as the temperature coefficient of expansion of concrete and steel, respectively.

From this table it is seen that at the time of making the last readings (18 months in the case of the first series and 11 months in the second) the high magnesia cements produced concrete showing as good a deportment so far as "expansion" is concerned as the low magnesia ones. However, no definite conclusion should be drawn at present, any disintegration due to late hydration of magnesia or its compounds would hardly manifest itself sufficiently to be determined by this method for some time yet.

Attention should be drawn to Burns 25 and 26. These were unsound according to the boiling and steam tests—particularly the former. It will be noted that the former has increased

in length when stored in water at little over .2 per cent, while in air it has contracted but .014. This is in accordance with the usually accepted facts, though it would be expected that the contraction in air would have already turned to an expansion to such a degree that the present length would be greater than the original. Burn 26, however, in air is acting as a sound cement, while in water it also shows a contraction—which is quite anomalous even for a sound cement. The table does show the great

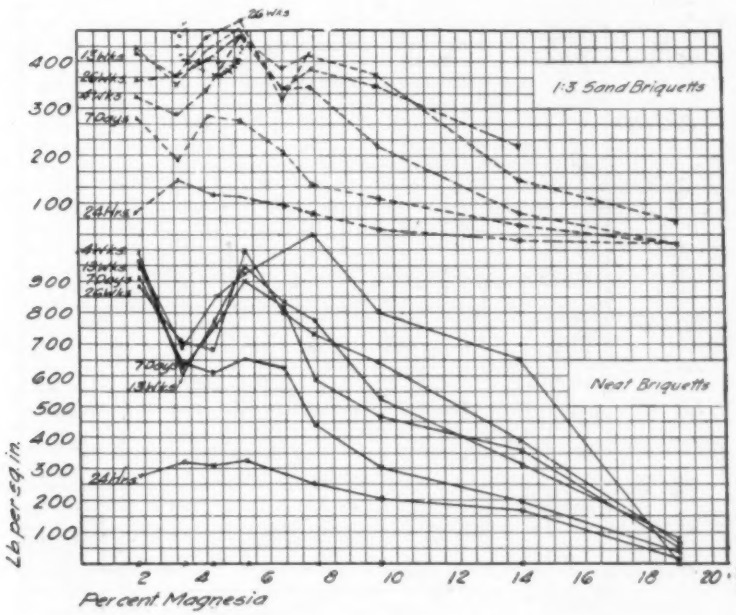

FIG. 1.

difference between concrete from different cements—this is even more clearly seen when the results obtained from other bars under measurement at this laboratory are examined. However, it would be premature to say that differences in the coefficient of expansion of various concretes are due to the use of a different cement—this is but one of the variables entering into this material—it is possible to conceive that differences in the consistency and degree of tamping would allow of very great difference in the coefficient.

STRENGTH DEVELOPED.

The strength specimens made were of the same kind and were stored in the same manner as in the first series. The results of the tests of these are shown in Table IV and Fig. 1, 2, 3. On the whole the strengths are lower than those obtained in that series, as would be expected from the higher alumina and lower lime con-

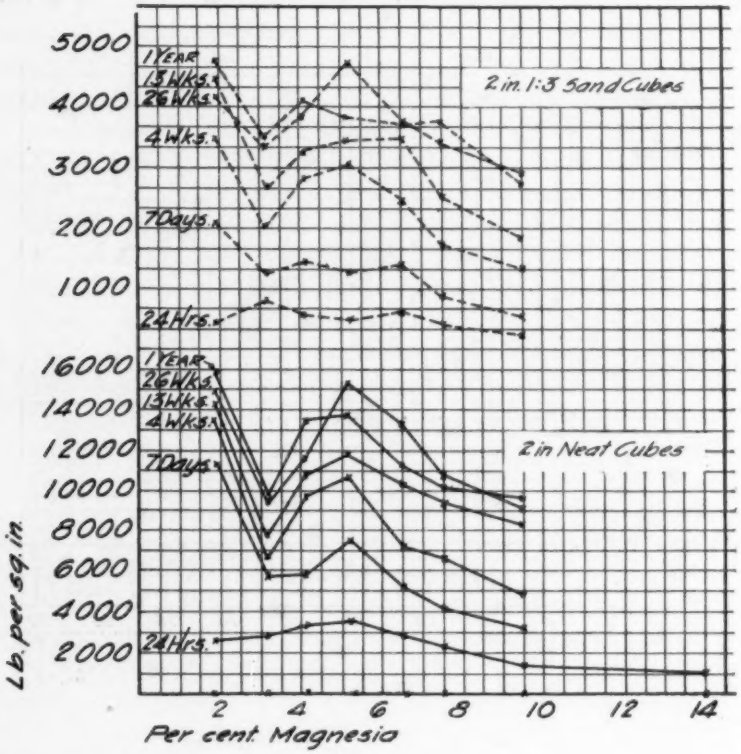

FIG. 2.

tent. However, the cement in the second series containing the highest magnesia, which would pass standard specifications (using the requirements for tensile strength at 28 days as a criterion) is number 39 (6.62 per cent MgO), whereas, in the first series it is number 28 containing about the same amount of magnesia, 6.4 per cent. But on examining the results at the 13 and 26 week

periods, it is seen that very satisfactory results are obtained with a cement containing 10.33 per cent MgO,—as in the first series where at the same periods the cements containing 9.50 per cent gave very good results. It is again to be noted that the alternate storage of specimens in the solution (2 per cent solution of equal

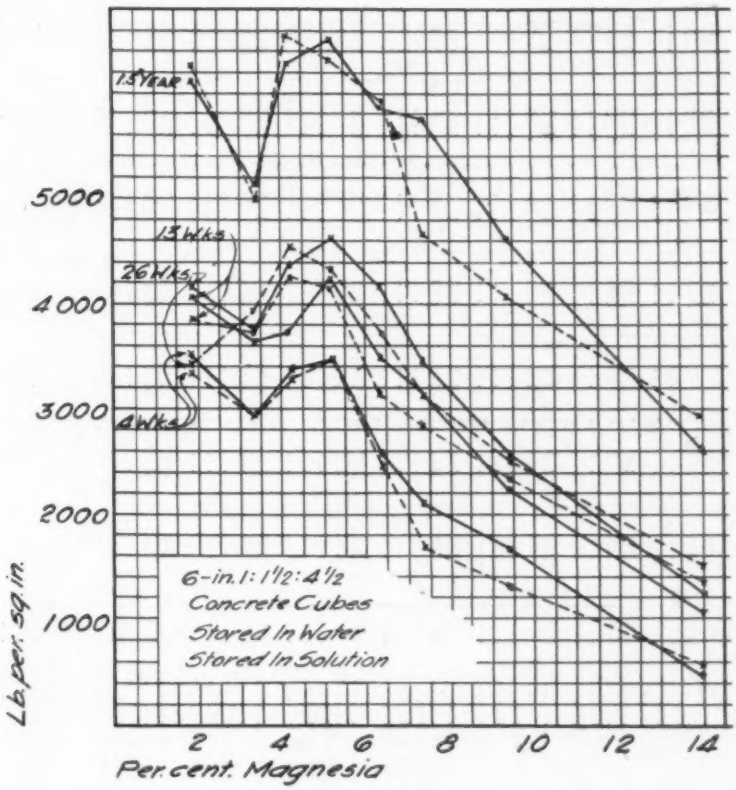

FIG. 3.

parts sodium chloride, sodium sulphate, magnesium chloride and magnesium sulphate) and drying, did not in any way materially affect the strength. The storage of a set of concrete specimens in air, which was not done in the first series, gave results which while very low, yet are in accordance with other results obtained at this laboratory when specimens have been stored in this man-

TABLE IV.—STRENGTH IN LB. PER SQ. IN. OF NEAT SAND AND CONCRETE TEST PIECES.

Burn No.		Tension Test Pieces.					Compression Test Pieces.†				
		24 hours.	7 days.	4 weeks.	13 weeks.	26 weeks.	24 hours.	7 days.	4 weeks.	13 weeks.	26 weeks.
33	Neat	25	24	99	79	124	127	311	453	719	2163
	1 : 3 sand	soft	soft	38	87	73	27	43	110	148	434
	1 : 1½ : 4½ concrete (Stored in water)*	...	...	...	...	...	....	....	....	....	....
	1 : 1½ : 4½ concrete (Stored in solution)*	...	...	...	...	...	....	....	....	....	....
34	Neat	59	165	190	279	258	892	1366	2486	5017	4833
	1 : 3 sand	33	42	41	93	130	147	137	545	896	1666
	1 : 1½ : 4½ concrete (Stored in closet)	...	...	...	...	...	....	....	133	476	787
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	63	105	77
35	Neat	147	210	142	210	244	1414	1695	1910	3471	4696
	1 : 3 sand	69	65	55	134	150	494	396	621	873	1628
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	408	768	1044
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	308	833	1127
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	320	378	512
36	Neat	230	242	431	644	625	1770	2904	4306	5893	6371
	1 : 3 sand	127	115	234	328	440	318	455	1394	2216	2563
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	1174	1868	2263
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	1003	1731	1917
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	1271	1957	2002
37	Neat	236	381	586	713	712	2142	4979	6969	8232	9897
	1 : 3 sand	90	160	305	448	400	386	844	2332	3550	3425
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	1660	2580	2714
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	2008	2611	2744
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	964	1262	1307
38	Neat	315	382	598	647	793	2170	4571	7679	8536	10183
	1 : 3 sand	112	168	252	366	418	489	911	1838	2018	2567
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	1836	2587	3232
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	1794	2624	3192
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	1094	1404	1473
39	Neat	359	495	630	733	719	2746	4554	7582	8378	9504
	1 : 3 sand	155	212	345	472	461	653	928	2227	1939	2792
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	2261	3406	3142
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	1972	3330	3381
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	1260	1362	1454
40	Neat	312	642	743	811	850	3058	6717	9178	10997	11750
	1 : 3 sand	136	274	368	428	431	568	1585	2631	2697	3896
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	2286	2859	3037
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	2364	3032	3440
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	1478	1612	1524
41	Neat	354	674	860	736	823	3517	8096	9104	10760	12400
	1 : 3 sand	133	289	406	449	470	673	1857	2696	3323	3758
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	....	....	2416	2887	3206
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	....	....	2045	2729	3180
	1 : 1½ : 4½ concrete (Stored in air)	...	...	...	...	...	....	....	1651	1800	1899

* No test pieces made. † (Sand test pieces were 2-in. cubes; concrete were 6-in. cubes.)

ner—it has been found that concrete specimens stored in air, without any wetting, will develop a strength at 26 weeks about equal to that obtained at the end of 4 weeks when the specimen has been stored in the damp closet.

SUMMARY.

The results obtained with the second series are so similar to those obtained with the first, that the summary given under the latter may be quoted again.

I. "Cement can be readily burned in a rotary kiln with a magnesia content of about 9.50 per cent before the resulting clinker will be materially different from that of a cement containing 3 per cent or less. Very high magnesia clinker (over 14 per cent) is very vitreous and dusts slowly, starting within about 24 hours."

II. "Petrographically no new constituents are present until about 9 per cent MgO is reached when small quantities of monticellite are noticed, with still increasing amounts spinel occurs. Both of these are non-hydraulic and if the cement is treated with dilute or concentrated hydrochloric acid, are largely insoluble." In the second series, owing to the high alumina and low lime, the new magnesia compounds appear at a low magnesia content, the Burn containing 7.8 per cent magnesia showing a very small quantity of monticellite.

III. "Pats made of a cement as high in magnesia as 18.98 per cent were sound after 28 days in air and water, when placed in boiling water or steam at the end of 24 hours they cracked slightly but were no softer than when removed from the molds. Pats made from cement with lower percentages of magnesia remained in excellent condition after all tests." The pats in the second series were even more satisfactory than those in the first series.

IV. "Cements containing up to 9.5 per cent magnesia showed normal initial set with a slight tendency toward slower final set. With a greater content, there was a quick initial set accompanied by a very marked rise of the temperature; with the highest magnesia cement made, the initial set determined with the Vicat needle was quick, accompanied by a rather marked evolution of heat—this heat being rapidly dissipated

TABLE V.—STRENGTH IN LB. PER SQ. IN. OF NEAT SAND AND CONCRETE SPECIMENS OF THE FIRST SERIES.

Burn No.	Kind of Specimen.	Tension. Tested at the end of						Compression. Tested at the end of						
		24 hours.	7 days.	4 weeks.	13 weeks.	26 weeks.	1 year.	24 hours.	7 days.	4 weeks.	13 weeks.	26 weeks.	1 year.	1.5 years.
16	Neat	275	925	965	951	893	951	2528	11343	13469	14238	14849	15793	....
	1 : 3 sand	72	291	322	410	365	414	398	2039	3516	4522	4199	4666	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	3491	4067	4081	....	6133
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	3388	3829	3435	....	6245
25	Neat	329	645	623	608	704	693	2955	5233	6840	7610	9162	9502	....
	1 : 3 sand	156	193	281	363	362	347	712	1284	1999	2656	3204	3374	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	2910	3625	3765	....	5084
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	2932	3756	3951	....	4996
26	Neat	305	609	756	764	688	844	3102	5818	9851	10855	11710	13507	....
	1 : 3 sand	128	291	336	403	445	421	555	1461	2725	3353	3761	4088	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	3275	3776	4379	....	6238
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	3351	4261	4564	....	6558
27	Neat	329	657	911	957	1015	928	3015	7614	10812	11821	15388	13583	....
	1 : 3 sand	108	275	445	443	480	459	515	1326	3042	3379	4754	3896	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	3410	4228	4605	....	6528
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	3427	4194	4318	....	6276
28	Neat	292	627	821	827	812	795	2833	5560	7206	10363	13181	11372	....
	1 : 3 sand	99	212	339	381	321	336	640	1380	2504	3548	3715	3603	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	2484	3493	4185	....	5843
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	2466	3173	3771	....	5875
29	Neat	258	445	591	774	723	1062	2268	4184*	6787	9438	10923	10321	....
	1 : 3 sand	91	149	341	427	430	376	395	879	1708	2618	3368	3688	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	2059	3171	3431	....	5742
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	1675	2813	3119	....	4650
30	Neat	209	300	464	543	647	800	1318	3078	4794	8112	9089	9730	....
	1 : 3 sand	58	110	217	378	367	355	227	454	1324	1809	2977	2707	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	1616	2254	2589	....	4610
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	1305	2343	2563	....	4068
31	Neat	170	196	359	311	377	652	†	†	†	†	†	†	....
	1 : 3 sand	29	52	79	160	186	224	†	†	†	†	†	†	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	483	1040	1248	....	2608
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	...	...	...	...	....	....	533	1342	1488	....	2989
32	Neat	27	30	38	77	73	*	292	330	322	564	....	*	....
	1 : 3 sand	24	26	27	68	102	*	117	133	140	288	....	*	....
	1 : 1½ : 4½ concrete (Stored in water)	...	...	...	...	...	...	....	....	†	†	†	†	....
	1 : 1½ : 4½ concrete (Stored in solution)	...	...	....	...	...	...	....	....	†	†	†	†	....

* Badly cracked. † No test pieces made.

in the smaller less insulated pat gave a slow initial set with the Gilmore needle. The final set was very slow." The time of set obtained in the second series is remarkably similar.

V. "The strength developed either by the neat cement or 1 : 3 mortars or 1 : 6 concrete up to periods of half a year, shows that cements containing as much as 7.5 per cent magnesia are satisfactory. Further, the increasing magnesia reduces the rate of hardening, so that at the late periods cements with a higher content have rather commendable strengths. Up to this period a 2 per cent solution of equal parts sodium chloride, sodium

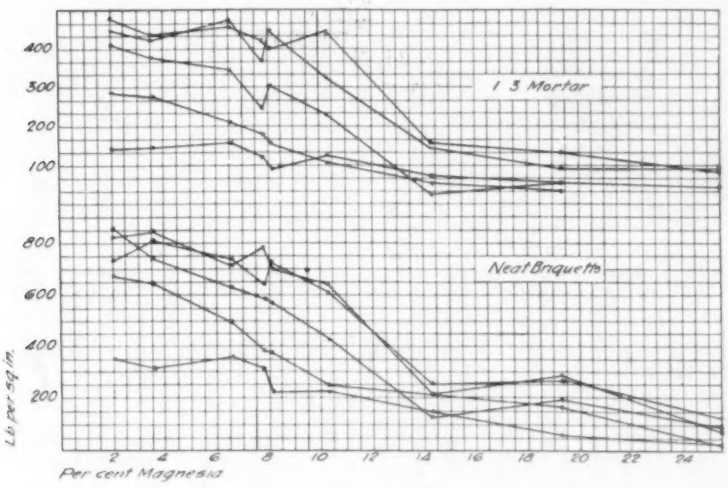

FIG. 1A.

sulphate, magnesium chloride and magnesium sulphate has no injurious effect." As noted before, generally the strength of the second series is somewhat lower than in the first series, but the strengths with a cement of 7.8 per cent magnesia content are very satisfactory.

STRENGTH OF LATER SPECIMENS OF THE FIRST SERIES.

In Table V and Fig. 1a, 2a, and 3a is shown the strength of in specimens of the first series. This table now includes the one year small specimens and the year and a half concrete specimens.

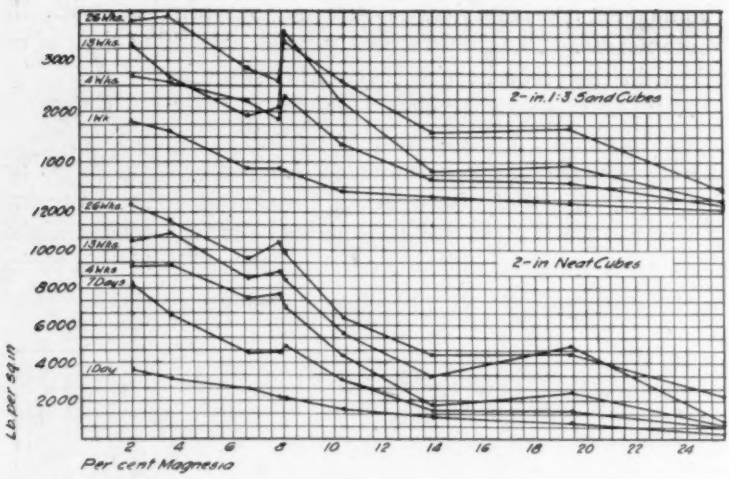
26 Wks.
13 Wks.
4 Wks.
1 Wk.
2-in. 1:3 Sand Cubes
26 Wks.
13 Wks.
4 Wks.
7 Days
1 Day
2-in Neat Cubes
Lb. per sq. in.
Per cent Magnesia

FIG. 2A.

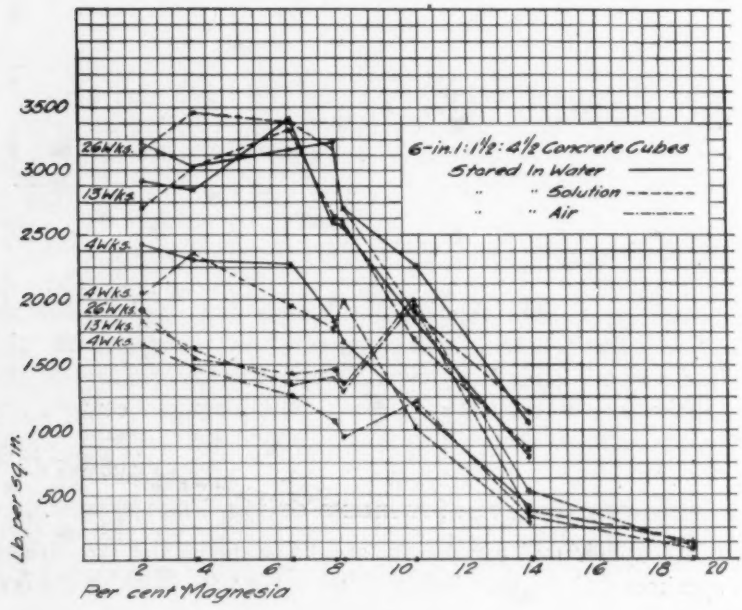
6-in. 1:1½:4½ Concrete Cubes
Stored In Water
" " Solution
" " Air
26 Wks.
13 Wks.
4 Wks.
4 Wks.
26 Wks.
13 Wks.
4 Wks.
Lb. per sq. in.
Per cent Magnesia

FIG. 3A.

FIG. 6.—A CRACK OF ONE OF THE ONE YEAR BRIQUETTES OF BURN 33, FILLED WITH CRYSTAL OF CALCIUM SULPHO-ALUMINATE. MAG. 18 DIA.

FIG. 7.—A MASS OF VERY FINE "SILKY" NEEDLES OF CALCIUM SULPHO-ALUMINATE, SPANNING A CRACK OF ONE OF THE ONE YEAR BRIQUETTES OF BURN 33. MAG. 1 DIA.

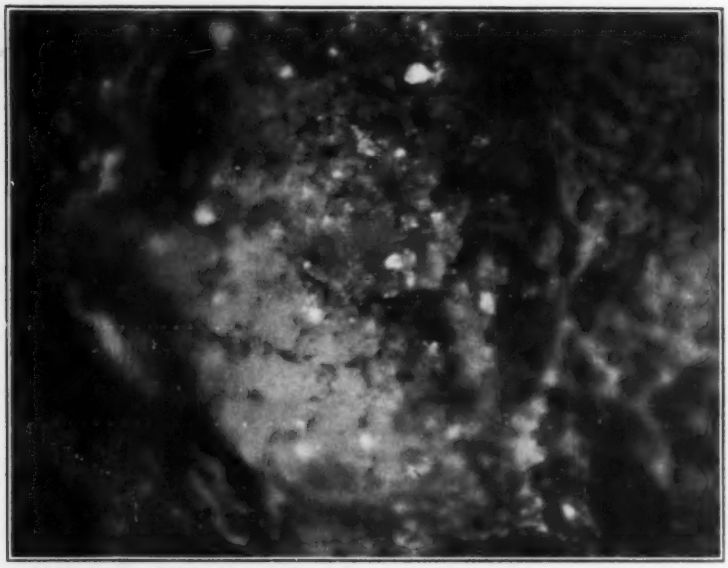

FIG. 8.—SHOWING ROUND AND HEXAGONAL WHITE CRYSTALS OF BOTH LIME AND MAGNESIA HYDRATE, SCATTERED OVER THE EXPOSED INTERIOR OF A ONE YEAR BRIQUETTE OF BURN 33. MAG. 22 DIA.

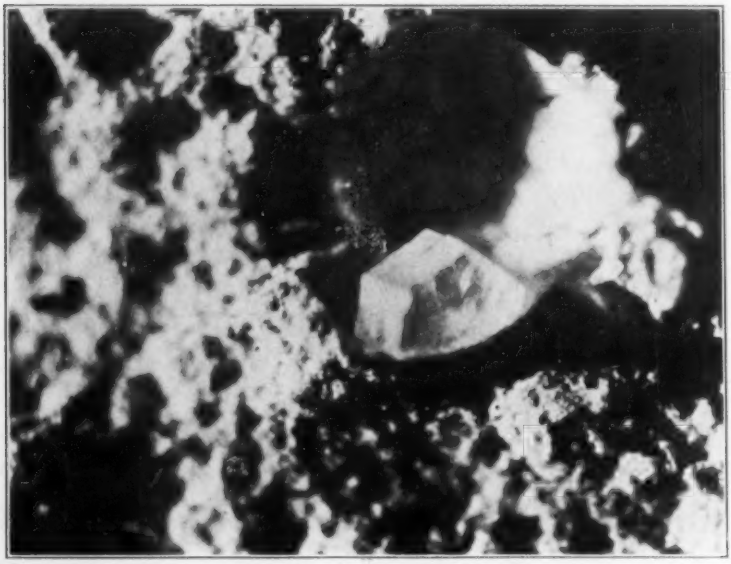

FIG. 9.—LARGE HEXAGONAL PRISM OF LIME HYDRATE ON THE EDGE OF A CAVITY IN THE INTERIOR OF A NEAT ONE YEAR BRIQUETTE OF BURN 33. MAG. 16 DIA.

The latter, after having been stored as outlined in the previous paper for one year, were stored in air alone. Just why there should be such a very large increase in strength is not apparent. But it is still clear that at this period the storage in the solution has not affected the high magnesia cements any more than the normal ones—though considering Burns 29 and 30 alone—this would not appear to be the case.

Examining the strength of the small specimens no marked retrogression in strength is noticed, except in Burns 27 and 28; but Burns 29 and 30 containing considerably more magnesia, show some very considerable increases. Burn 32, which never showed any marked strength and which contained 18.98 per cent magnesia, disintegrated before the end of the year. The neat tensile specimens are shown in Fig. 5. The cracks were filled with crystals of sulpho-aluminate of lime and the mineral brucite—the crystalline form of magnesium hydrate. The former is shown in Fig. 6 and 7 and some of the latter in Fig. 8. It is quite possible that some of the crystals of sulpho-aluminate of lime may be sulpho-aluminate of magnesium, but not enough data are at hand to determine this. The photographic representation of these crystals is rather difficult, owing to inability to have many of them in focus at one time, but their presence in each of the figures can be clearly seen. The round to hexagonal white spots shown in Fig. 8, are both crystals of magnesium hydrate and lime hydrate, but it is impossible to differentiate between them without removing them and determining their optical character.

In Fig. 9 is shown a crystal of lime hydrate on the edge of a cavity of one of the above-mentioned briquettes. This is by far the largest crystal of this material observed in this laboratory; larger hexagonal plates have been observed but no prisms of this size. The presence of lime hydrate crystals in a cement containing 25.5 per cent magnesia is very noteworthy.

Acknowledgments are due to Mr. A. A. Klein for the petrographic examinations and to Mr. E. R. Gates for superintending the molding and breaking of all test pieces.